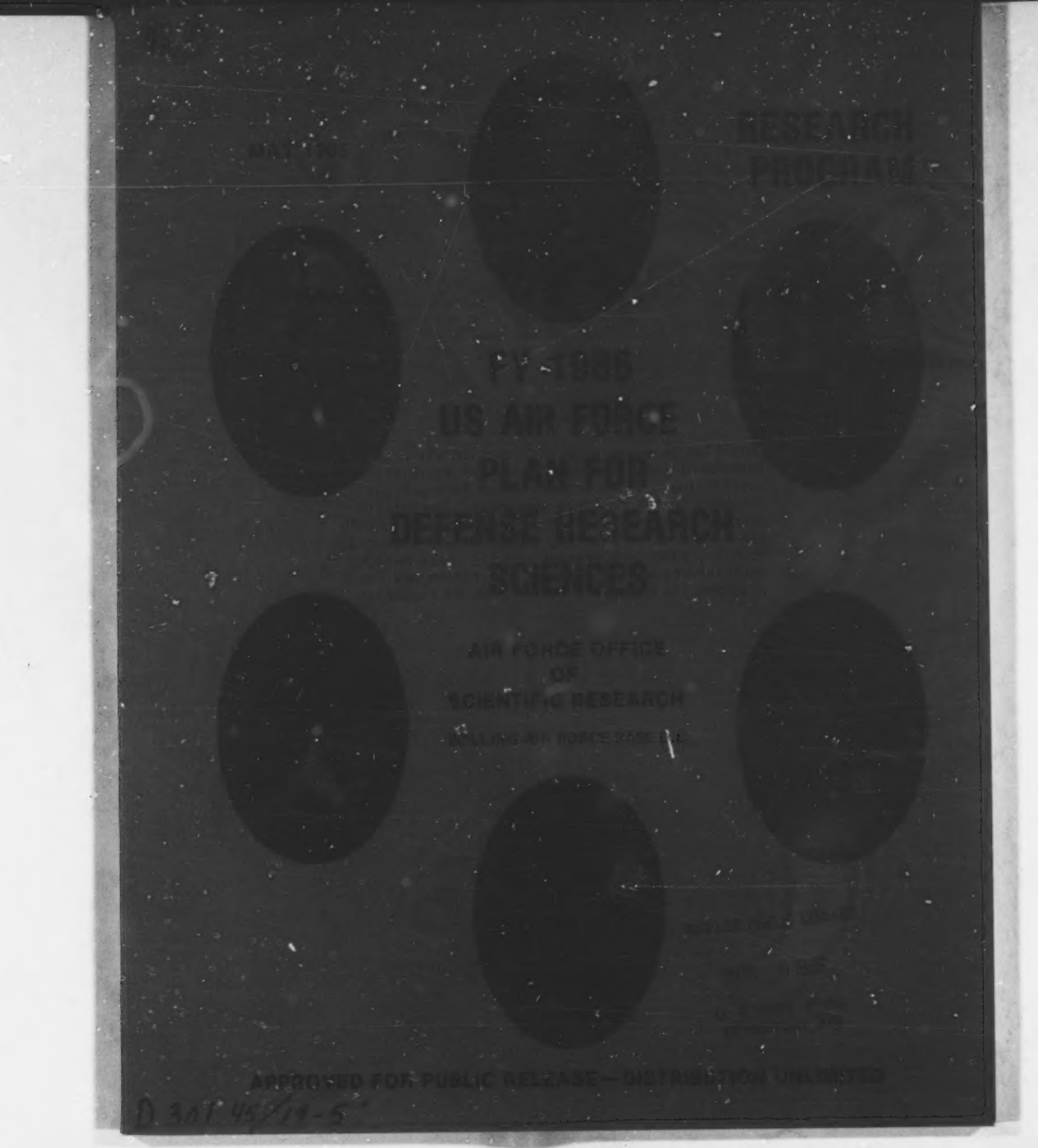
RESEARCH
PROGRAM OF
FY 1986
US AIR FORCE
PLAN FOR
DEFENSE RESEARCH
SCIENCES
AIR FORCE OFFICE
OF
SCIENTIFIC RESEARCH
BOLLING AIR FORCE BASE, DC
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FY 1986
US AIR FORCE
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DEFENSE RESEARCH
SCIENCES

MAY 1985

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INTRODUCTION

This Plan describes the Air Force Defense Research Sciences Program that the Air Force Office of Scientific Research (AFOSR) will manage during Fiscal Year 1986 with funds appropriated under Program Element 61102F, USAF Defense Research Sciences (DRS). It includes activities that will be performed in Air Force Laboratories and under contract in industrial and university facilities.

In publishing this Plan, AFOSR is responding to the Air Force Systems Command (AFSC) Research Planning Guide (Research Objectives) of February 1984.

The Air Force Defense Research Sciences Program provides the fundamental knowledge needed for solving military problems, avoiding a technological surprise, and finding technological alternatives. It describes the research planned in eight technical areas: Life Sciences, Materials, Geophysics, Aerospace Vehicles, Propulsion and Power, Weaponry, Electronics, and Computational Sciences.

THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFOSR)

ORGANIZATION

AFOSR is directly subordinate to HQ AFSC, and includes Detachment 1, AFOSR, European Office of Aerospace Research and Development (EOARD); Detachment 2, AFOSR, Frank J. Seiler Research Laboratory (FJSRL); and the Far East Operating Location (AFOSR/FE).

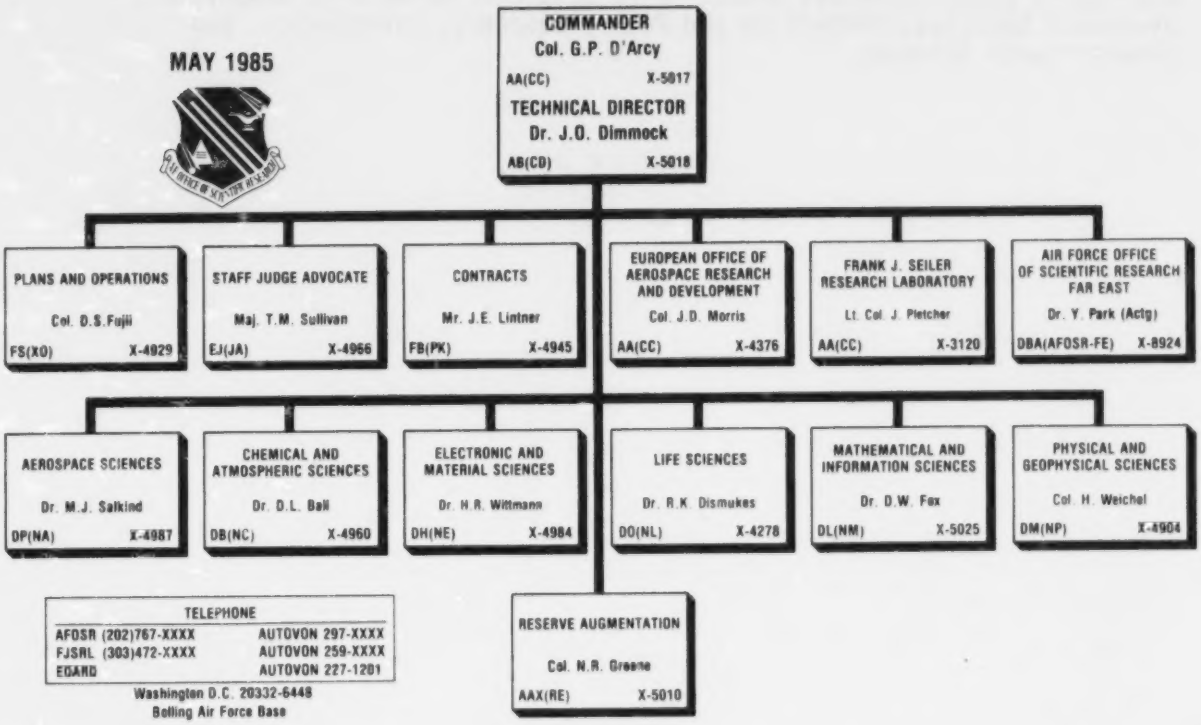

Figure 1. The Air Force Office of Scientific Research

MISSION

The Air Force Office of Scientific Research (AFOSR) is the Single Manager of the Air Force Defense Research Sciences Program funded by Program Element 61102F. AFOSR is responsible for planning, managing, implementing and controlling a high quality basic research program. Specifically, AFOSR's goals are (1) to maintain technological superiority in the scientific areas relevant to Air Force needs; (2) to prevent and create technological surprise; (3) to maintain a strong science and technology infrastructure in the Air Force Laboratories, industry and universities; and (4) to complement the national research effort.

To meet this goal, AFOSR

-- Manages an extramural research program at universities, not-for-profit and industrial research organizations.

-- Provides overall management for research conducted on-site and under contract at the following Air Force organizations:

Air Force Armament Laboratory
Air Force Geophysics Laboratory
Rome Air Development Center
Air Force Rocket Propulsion Laboratory
Air Force Wright Aeronautical Laboratories
- Flight Dynamics Laboratory
- Materials Laboratory
- Avionics Laboratory
- Aero Propulsion Laboratory

Air Force Human Resources Laboratory
Aerospace Medical Division
- USAF School of Aerospace Medicine
- Air Force Aero-Medical Research Laboratory

Air Force Weapons Laboratory
Air Force Engineering and Services Laboratory

- Operates and administers three subordinate units; EOARD, FJSRI and AFOSR/FE. EOARD monitors European and Middle Eastern research and development, AFOSR/FE monitors research in the Far East and FJSRI performs research in aerospace mechanics, chemical sciences, and Physics, as well as providing research opportunities for USAF Academy faculty and cadets.

-- Conducts several special programs.

- Maintains an Air Force Reserve group that, in addition to its peacetime duties, is capable of providing research support to solve Air Force problems during a national emergency.

RESEARCH PLANNING

FORMULATION

The Air Force research planning and review process is the formal mechanism by which a desired investment strategy is translated into a research program. This planning is a stepwise continuous process that is formalized by documentation and a series of reviews that are scheduled throughout the fiscal year. The entire process, from initial guidance to final review of the research results, spans three years . A typical cycle is shown in Figure 2.

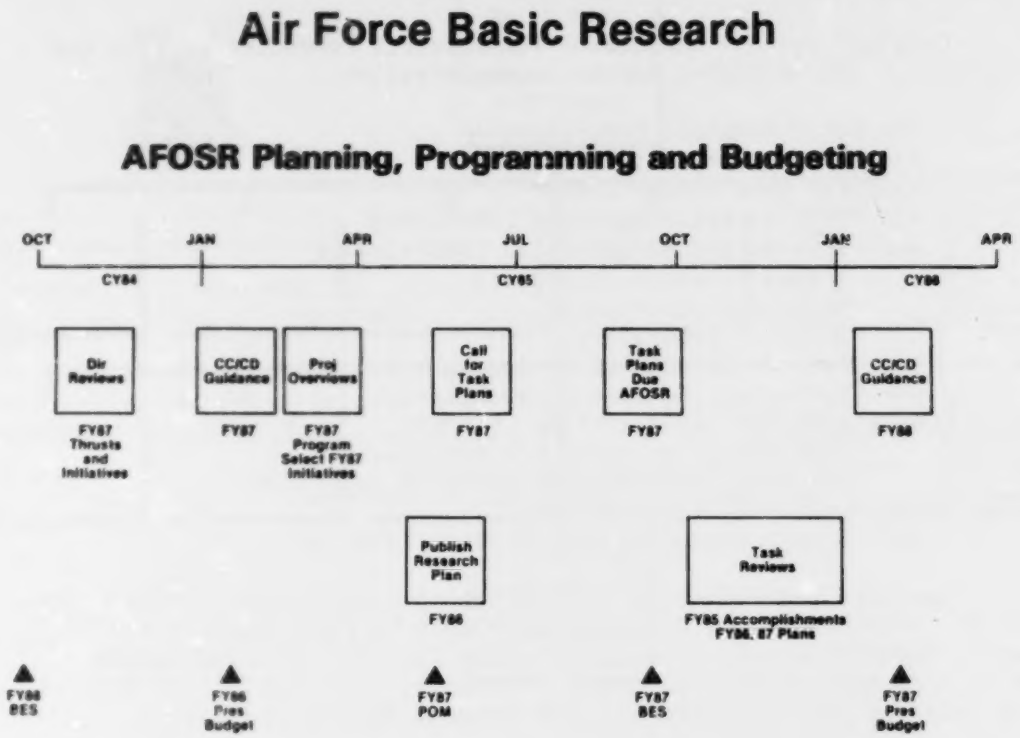

Figure 2. AFOSR Planning Process

The planning process starts in September 25 months before the start of the fiscal year, with Project level thrust recommendations provided by the Scientific Directors to the Commander. This provides input for the Air Staff RDT&E (J-Panel) POM review. Guidance for the formulation of the Core program and Initiatives is provided to the Scientific Directors by the Commander and Technical Director in January, twenty one months before the fiscal year start. A complete review of the proposed program including both Core and Initiatives is held with Laboratory participation in March. Resultant budget guidance is provided to the Scientific Directors in April which also forms input to AFSC for the POM 18 months before the start of the fiscal year. Directorate Task allotments are approved by the Commander and Technical Director in May.

The Scientific Directors distribute the Project funds to the Tasks within the Project. On the basis of the funding guidance, Task Plans are developed, and submitted in August to the Scientific Directors for review and approval by December. The Defense Research Sciences Plan is published in May five months before the start of the fiscal year.

Finally in October and November following completion of the final year, each Task Manager briefs the Commander and the Scientific Directors on Task accomplishments, the research program to be attempted during the following year, and the fiscal status of the Task. These reviews are frequently held at the Air Force Laboratories most actively involved in the program. The AFSC staff, the Chief Scientists of the Laboratories and DOD personnel also attend these briefings. Programmatic adjustments are made on a continuing basis to reflect the most current funding picture. Necessary technical program alterations are accomplished.

Throughout the process, approved plan alterations and funding changes are included in the "living" plan which is maintained within AFOSR on a computer-based system.

COORDINATION

AFOSR coordinates its diversified, broad-based research program with Air Force Laboratories, Product Divisions and Centers, other Services, and various Federal agencies. Much of the basic research program feeds directly or indirectly into the Laboratory Exploratory Development (6.2) programs. However, some research efforts result in revolutionary breakthroughs which initiate new 6.2 programs. AFOSR personnel brief the various Product Divisions and Centers on selected scientific achievements and on-going research that applies to their needs. The resesearch program is also briefed annually to OSD and HQ AFSC at the Investment Strategy Review.

AFOSR also coordinates its research program with the programs of the other Services through scientific meetings, workshops, and exchange of proposal lists and funding actions.

In addition, AFOSR coordinates research efforts with various other Federal agencies, including the National Aeronautics and Space Administration, Federal Aviation Administration, National Science Foundation, Department of Energy, National Institutes of Health, US Geological Survey, National Security Agency, Defense Nuclear Agency, Defense Advanced Research Projects Agency, Environmental Protection Agency, National Oceanographic and Atmospheric Agency, and National Bureau of Standards.

Industry conducts Independent Research and Development (IR&D) programs which are evaluated by an assigned DOD agency. AFOSR has oversight responsibility for IR&D at eight industrial laboratories that specialize in basic and applied research. They are: GE/Corporate R & D (Schenectady NY), Honeywell/Corporate Tech Ctr (Bloomington MN), Honeywell/Systems & Research Center (Minn MN), IBM/Research Div (Yorktown Hts NY), Martin Marietta/Laboratories (Baltimore MD), McDonnell Douglas/Research Labs (St Louis MO), Rockwell/Science Center (Thousand Oaks CA), and TRW/Electronics & Defense (Redondo Beach CA). This oversight responsibility involves technical plan evaluations and on-site visits that give Air Force scientists an opportunity to assess industrial programs and to encourage industrial researchers to include research of interest to the Air Force in their plans. Managers of Air Force research projects have available to them copies of relevant IR&D summaries from the Defense Technical Information Center.

COMMANDER'S ASSESSMENT

Starting in FY 78 the funding for Air Force Basic Research shows a positive trend (Figure 3). This has reversed a decade of decreasing resources that reduced the buying power of the research program by 50 percent. This reversal resulted from OSD guidance to provide 10 percent real growth per year. Although this growth goal has not been realized because of inflation and reductions in the budget made by Congress, the use of a 10 percent real growth factor during the budget planning stages has yielded a smaller but real growth in the appropriation.

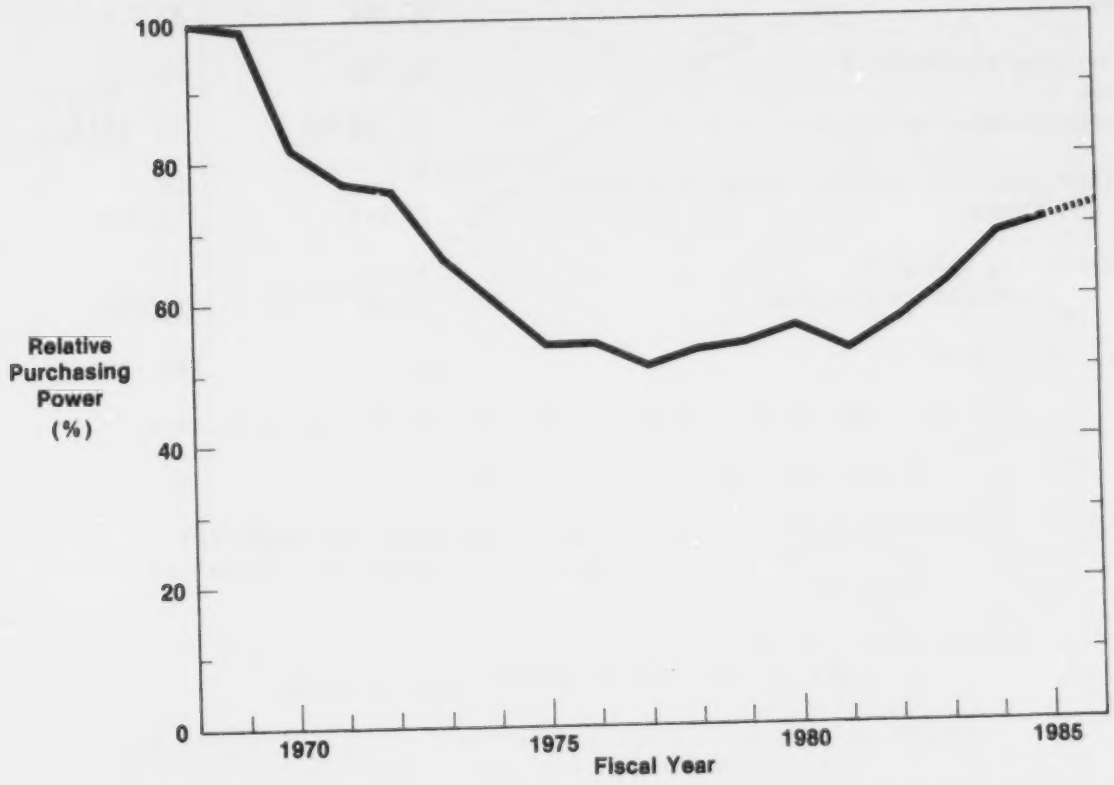

Figure 3. PE 61102F Relative Purchasing Power

Table 1 shows the breakdown of FY 85 funds as reported in the Research Plan published in April 1984 and that actually appropriated.

TECHNICAL AREA	FUNDING ($K) FY 85 PLANNED PROGRAM ($K)*	FY 85 ACTUAL PROGRAM ($K)**
Life Sciences	15,103	15,557
Materials	29,677	27,786
Geophysics	22,841	21,438
Aerospace Vehicles	21,488	21,463
Propulsion and Power	21,417	22,176
Weaponry	20,362	21,175
Electronics	35,282	36,575
Computational Sciences	16,165***	16,165***
Other (Special faculty research programs and support)	13,945	13,945
University Research Instrumentation Program	10,000	10,000
TOTAL	190,115	190,115

*FY 1985 US Air Force Plan for Defense Research Sciences

**Based upon appropriation of 190,115

***Computational Sciences was a non-additive technical Area in FY 85. It starts as an independent technical Area in FY 86.

TABLE 1. FY 1985 PE 61102F Funding Track

Figure 4 shows the trends since 1981 in the Laboratory Research Program. The personnel curve represents the numbers of Laboratory scientific and engineering (S&E) manyears utilized in performing the basic research effort. The Laboratory S&E personnel devoted to in-house research in FY 84 was equal to about 6.3 percent of the Laboratory S&E personnel. The funding curve reflects the total basic research program at AFSC Laboratories. The 1985 and 1986 data points are estimated.

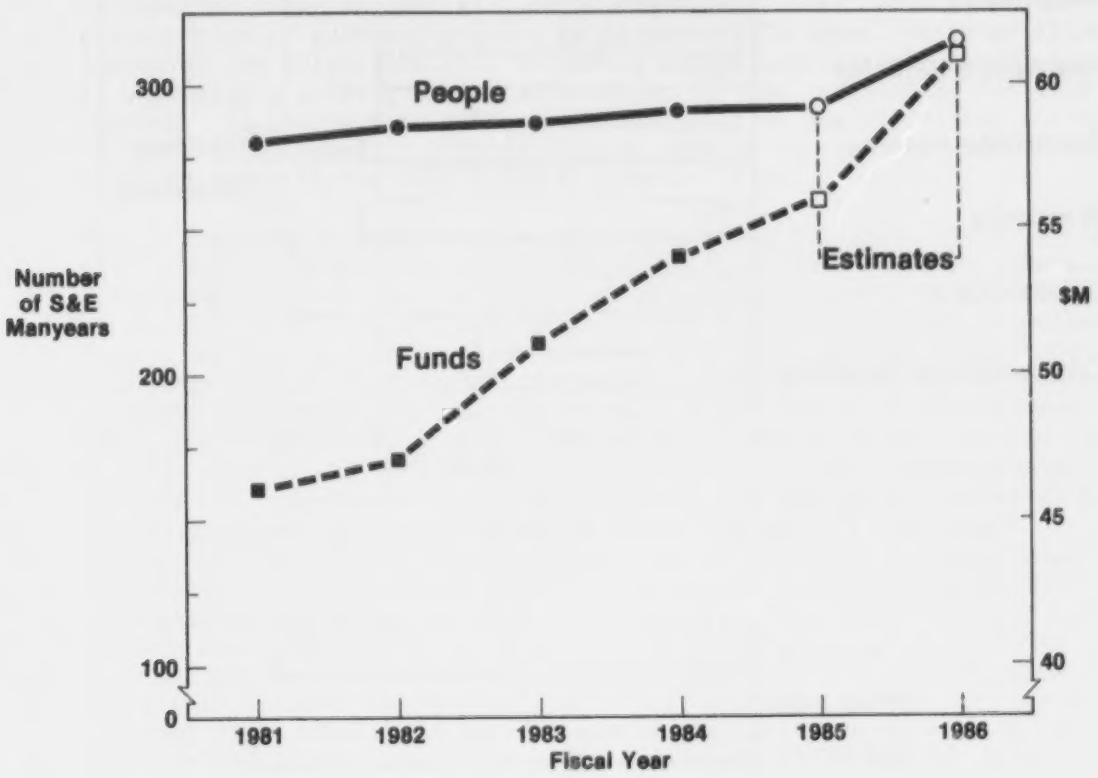

Figure 4. Laboratory Research Programs Manpower/Funding

Although research program financial management is carried out by discipline-oriented Projects and Tasks, investment technical planning is carried out in terms of the eight technical areas and 35 subareas of the AFSC Research Planning Guide. Figure 5 shows the funding alloted to each of the eight technical areas in FY 86. Figure 6 shows how the research efforts planned for these eight technical areas translate into the project funding in FY 86.

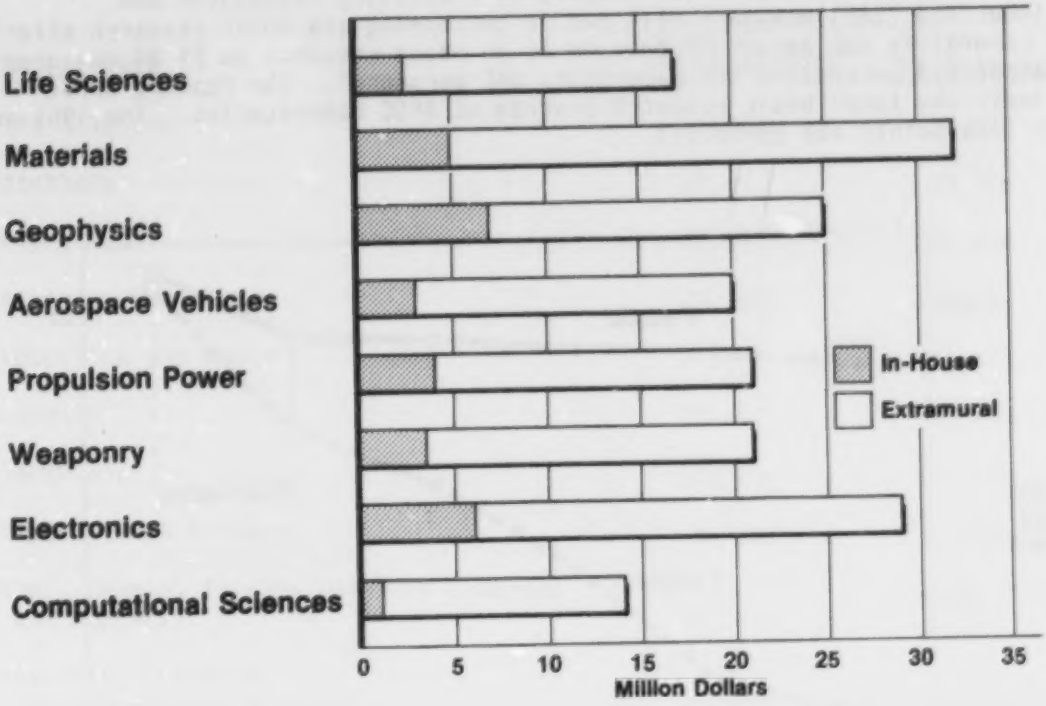

Figure 5. FY 1986 Air Force Research Funding by Technical Area

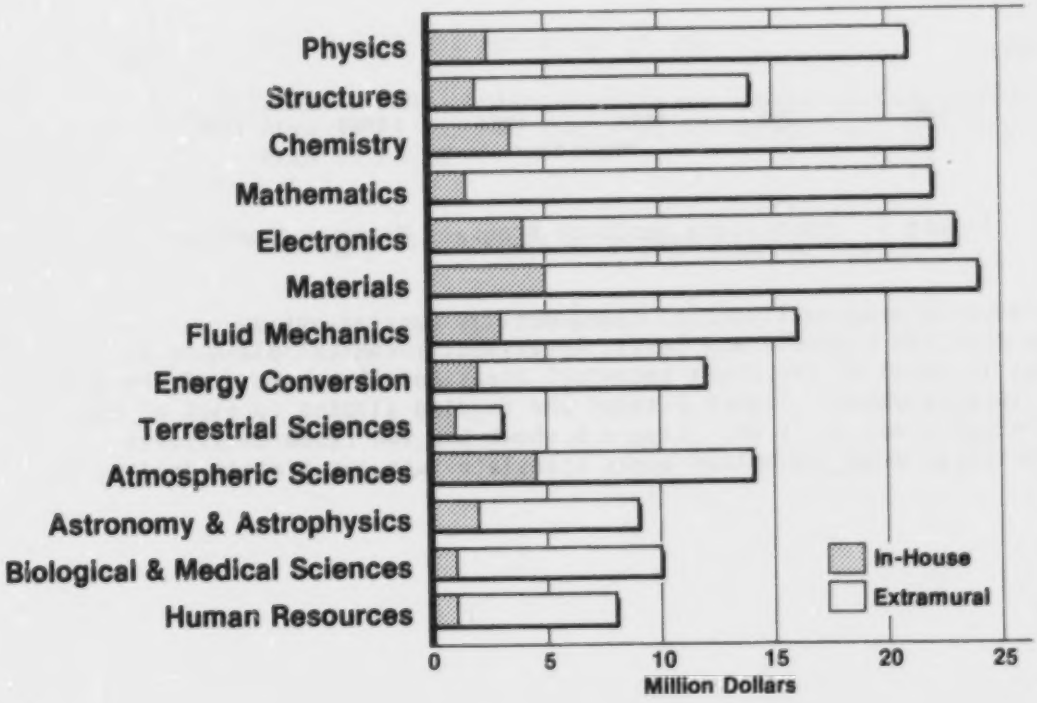

Figure 6. FY 1986 Air Force Research Funding by Project

New Research Initiatives

The FY 86 research funding request will permit the Air Force to carry out six new major initiatives:

Auditory Pattern Recognition. This initiative will examine the mechanisms by which complex sounds are recognized and will formulate theoretical models of the operation of the human auditory system. The knowledge generated will provide a quantitative description of how individuals process auditory information under various real-world conditions. This will allow the presentation of auditory signals to be matched to human characteristics, improving the intelligibility of speech and signals in noisy environments. It will also provide a basis for more appropriate audiometric tests of hearing. It should also guide the development of new algorithms for machine recognition of speech. This initiative will be carried out under Project 2313 and supports the Life Science Technical Area.

Middle Atmospheric Periodic Structure Associated Radiance. This initiative will investigate periodic structures in emitted radiance which some wavelike motions generate in the infrared. These structures are a potential source of clutter, a problem for Air Force Systems attempting target detection. Sources of such motions must be comprehended along with an understanding of wave propogation, frequencies, intensity variations, geographic occurrences, altitude dependence, and spatial extent. A comprehensive data base will be gathered using mobile, ground-based units. Supporting analyses and modeling will be used to aid in interpretation of results. This initiative will be carried out under Project 2310 and supports the Geophysics Technical Area.

Maneuverability. This initiative will pursue research into providing the capability for aircraft and missiles to operate and exploit unsteady aerodynamics including the post-stall regime. Post-stall maneuver can be done in about half the time of a conventional maneuver thus allowing first shot capability for improve air combat effectiveness. This research will exploit the recent insights gained in unsteady aerodynamics to provide enhanced lift. This will be strongly coupled with new thrusts in controls research which allow nonlinear, real-time computation control, coupled with structural and propulsion system response. Human factors limitations must be addressed as the new maneuvers are radically different from current flight regimes. This initiation will be carried out under Project 2307 and supports the Aerospace Vehicle Technical Area.

Laser Physics. The objective of this initiative is to find more efficient and scalable electically pumped laser systems in the visible/uv region and to develop a visible chemical laser by using Anti-Stokes Raman upconversion from the infrared. Presently there exist no efficient electrically excited visible/ultraviolet laser systems. Therefore large amounts of electrical power are required to deliver small amounts of power on target. Also, no high power chemical lasers exist that produce radiation in the visible region of the spectrum, that which is most easily propogated through the atmosphere. Research efforts will include discharge pumping of inert gas

mixtures, discharge initiation chemical reactions, cross section data from drift velocity measurements and efficient Anti-Stokes Raman Media. This initiative will be carried out under Project 2301 and supports the Weaponry Technical Area.

Monolithic Millimeter Wave Integrated Circuits (MMIC's). This initiative will seek to identify materials improvements, device designs and automatable processing techniques supporting the development of monolithic microwave and millimeter wave integrated circuits MICs and MMICs (MMICs and MMMICs). Monolithic refers here to the fabrication on a single semiconductor chip of all needed active and passive components such as transistors, capacitors, inductors and interconnections. (In hybrid ciruits, two or more devices or chips must be interconnected). Basic research is needed in several areas to support the emergence of this technology. This includes work on substrates, active layers, device modeling, millimeter wave device designs and monolithic integration. Novel waveguiding approaches will be sought. Traveling and standing wave effects in the multilayered structures found in these applications will be studied. The development of distributed circuits will be explored. This initiative will be carried out under Project 2305 and supports the Electronics Technical Area.

Distributed Parameter Control. This initiative will build the base of scientific knowledge needed to design and control systems governed by partial and functional differential equations. Air Force applications include large flexible space structures, fluid flow control, combustion control and adaptive optics. Analysis and numerical algorithms will be central areas of research. Emphasis will be placed on understanding the fundamental problems with control of partial differential equations. This initiative will be carried out under Project 2304 and supports the Computational Sciences Technical Area.

RECENT ACCOMPLISHMENTS

AFOSR publishes a separate document "Recent Accomplishments of the Air Force Office of Scientific Research." Information on obtaining this and other AFOSR publications is contained at the back of this plan.

SPECIAL PROGRAMS

In addition to its regular research program, AFOSR conducts several special research programs. Under these programs, the Summer Faculty Research Program (SFRP), Graduate Student Summer Support (GSSSP) Program, and the University Resident Research Program (URRP), university faculty and graduate students are given an opportunity to bring new ideas into the Air Force research community and to take Air Force problems and practice back to their university environment. Approximately 944 faculty researchers have participated in these programs.

Summer Faculty Research Program (SFRP). This 10-week program emphasizes research efforts designed to enhance relationships between Air Force Laboratories, Centers, and Product Divisions, and university researchers. Specific objectives of the program are to--

a. Develop the basis for continuing research of interest to the Air Force at the faculty member's institution.

b. Stimulate continuing relations among faculty members and their professional peers in the Air Force.

c. Enhance the research interests and capabilities of scientific and engineering educators in scientific areas of interest to the Air Force.

The SFRP began in 1975 with 22 participants. In 1984 and 1985 there were 150 participants in the program. We plan to continue at that level in 1986. For research initiated under the SFRP, funding for the research to be continued at the educator's university is available under the AFOSR Minigrant Program. In 1984 and 1985 over 75 minigrants were awarded to participants of the SFRP. We plan to maintain this level in 1986. Universities, Air Force Laboratories, and other research activities have enthusiastically endorsed the SFRP.

Graduate Student Summer Support Program (GSSSP). This pilot program was begun during the summer of 1982 as an adjunct to the SFRP. Its objectives are to -

a. Provide a productive means for a graduate student to participate in research under the direction of a faculty member at an Air Force Laboratory or Center.

b. Stimulate continuing professional association among graduate students, their supervising professors, and professional peers in the Air Force.

c. Further the research objectives of the Air Force.

d. Expose graduate students to potential thesis topics in areas of interest to the Air Force.

In 1982, 17 graduate students (US citizens) represented 15 schools and 10 disciplines in science and engineering. The pilot program was extremely well received. In the

1984 GSSSP, 86 graduate students were selected to participate, and we plan to select 100 graduate students for the 1985 and 1986 programs.

University Resident Research Program (URRP). The URRP is designed to stimulate mutual research between Air Force Laboratories and institutions of higher education. AFOSR administers this program under the Intergovernmental Personnel Act. It enables highly qualified university faculty members to work for one year on research problems of interest to the Air Force at an Air Force research facility. Extension to a second year of residency is possible. Approximately 25 slots are allocated annually to the Laboratories under this program. Since the program began in 1977, approximately 112 highly qualified university researchers have participated in the program. Advertisements in professional journals serve to increase university awareness of the URRP.

Historically Black Colleges Program. In 1979, AFOSR initiated a program to make over 100 Historically Black colleges aware of opportunities in Air Force research and development. On December 4, 1979 a workshop was held at the Atlanta University Center in Atlanta, Georgia to encourage scientists from historically black colleges to become involved in the various research and professional programs the Air Force sponsors. Air Force personnel, including many Laboratory chief scientists, gave presentations about their research interests. Approximately 125 participants, who represented over 70 historically black colleges, attended. In 1981, AFWAL and AFOSR cofunded three regional workshops on Opportunities in Air Force Research and Development. The Atlanta University Center was the contractor for these workshops. They were held in early May at North Carolina A&T State University, Tennessee State University and Texas Southern University. Each workshop gave information about the basic purposes and research concerns of the Air Force; the role of Black institutions toward these concerns; and the professional programs available through Air Force research activities. In 1985 AFOSR sponsored a Research Opportunities Workshop at the 10th National Conference on Blacks in Higher Education. In attendence were over 60 members of HBCU's. The Technical Director, Directors, and Program Managers made presentations and discussed topics of interest to the attendees. During 1984 and 1985 the Special Faculty Programs manager visited over 50 Historically Black colleges and discussed opportunities in Air Force research and development with interested faculty researchers and administrators. Also during 1985 talks between Tuskegee Institute and AFOSR on assisting the Engineering School establish areas of equipment needs for their education and research program in the General Daniel

James Aerospace Center continued. Additionally, Tuskegee was the recipient of an AFOSR grant that provides support for Tuskegee's 84 summer research apprenticeship program. The apprenticeship program is directed towards bright and promising minority high school students that have exhibited skills in science and mathematics. It is anticipated that this program will continue through 1985 and 1986.

The AFSC/National Research Council (NRC) Resident Research Associateship Program. This program provides postdoctoral scientists and engineers opportunities to research problems of their own choice that are compatible with the research interests of selected sponsoring Air Force Laboratories. In this way, these researchers contribute to the overall research effort of the laboratories. This program is intended to be analogous to fellowships, associateships, and similar temporary programs at the doctoral level in universities and other organizations.

Since 1982 AFOSR has sponsored a Research Sabbatical Program. This program provides the opportunity for an AFOSR civilian scientist to spend up to a year performing research which will update the scientist's knowledge of the state-of-the-art in his/her field. The Sabbatical Program is open to scientists who have worked at AFOSR for at least five years and who are not planning retirement within five years.

In addition, AFOSR is participating in the Defense Small Business Innovation Research Program and the DOD-University Research Instrumentation Program.

Defense Small Business Innovation Research Program (SBIR). This program is designed to encourage small businesses that have strong research and development capabilities in science and engineering to submit proposals to the Departments of the Army, Navy, Air Force, the Defense Advanced Research Projects Agency, and the Defense Nuclear Agency. This program will support high quality research and development proposals on innovative concepts related to important defense-related scientific or engineering problems. If the research is successful, these opportunities could significantly benefit the public.

DOD-University Research Instrumentation Program. AFOSR, with the Army Research Office and the Office of Naval Research, is participating in a five-year DOD program to upgrade university research instrumentation. The goal of this program is to improve the capability of universities to perform research in support of national defense. This program of support for the acquisition of research equipment has the primary purpose of stimulation and support of basic research underlying the technology goals of the Department of Defense (DOD). This program began in Fiscal Year 1983.

PROGRAM MANAGER: Dr R K DISMUKES
Telephone: (202) 767-4278

TECHNICAL AREA 1: LIFE SCIENCES

INTRODUCTION

This program is directed toward finding ways to protect Air Force personnel and improve their performance.

People are indispensible to Air Force systems. Human performance is crucial to success or failure of a mission. But Air Force systems are evolving so rapidly that they are outstripping human performance and endurance capabilities. If we are to use sophisticated equipment optimally and capitalize on rapid developments in engineering, we must understand human functional capabilities much better.

Increasing the effectiveness in selecting, training, and using people in Air Force jobs is the objective of research on the basic nature of learning processes and mental abilities. Research on the human mechanisms for processing sensory information will help us learn how to make machines that present information to and respond to information from human operators most effectively. It will also contribute to the development of sophisticated machines that can recognize speech and analyze visual images. Research on the mechanisms that control neuronal responsiveness will help us find ways to enhance the performance of humans operating under stressful conditions and to decrease the negative effects of fatigue and sleep disruption.

Improved protection is the objective of research on the biological effects of toxic chemicals and electromagnetics radiation.

FY 86 PLANNED FUNDING:

MAJOR THRUST INITIATIVE:	FUNDING ($K)
Auditory Pattern Recognition	1475
TOTAL	1475

SUBAREA NUMBER	TITLE	FUNDS SPTG SUBAREA ($K)
1.1	Manpower Selection and Training	576
1.2	Information Processing	6227
1.3	Aerospace Physiology	5013
1.4	Bioenvironmental Hazards	3485
	TOTAL	15301
	TECHNICAL AREA TOTAL	16776

TECHNICAL AREA: Life Sciences

MAJOR THRUST INITIATIVE: Auditory Pattern Recognition

GENERAL OBJECTIVE: This research examines the mechanisms by which complex sounds are recognized, and it formulates theoretical models of the operation of the human auditory system. The knowlege generated will provide a quantitative description of how individuals process auditory information under various real-world conditions. This will allow the presentation of auditory signals to be matched to human characteristics, and it will provide a basis for more appropriate audiometric tests of hearing. It should also guide the development of new algorithms for machine recognition of speech.

RESEARCH EFFORTS:

Auditory Pattern Recognition: This research will emphasize psychophysical techniques such as presenting complex sounds to human listeners and measuring the accuracy or speed of identification, recognition, discrimination or audibility. The measured responses can be related to competing models of sensory processing and can be used to develop more sophisticated models. One goal is to discover which acoustic features of speech and other complex sounds are extracted by the auditory system. Another goal is to understand the effects of context and memory on recognition of sequences of auditory patterns.

FY 86 PLANNED FUNDING: $1475K

AFOSR Focal Point: Dr J F Tangney
Dr A R Fregly

Telephone: (202) 767-5021

TECHNICAL AREA: Life Sciences

SUBAREA NUMBER AND TITLE: 1.1 Manpower Selection and Training

GENERAL OBJECTIVE: This research provides a theoretical and empirical framework for testing mental abilities and assigning personnel to appropriate Air Force specialties. It will improve training by allowing instructional techniques to be matched to the mental operations involved in learning and memory.

RESEARCH EFFORTS:

1. Learning Abilities (RO 1.1.1 and RO 1.1.3): We are developing a theory-based system of ability measurement that will account for individual differences in skill and knowledge acquisition rates and performance levels. New techniques are needed for evaluating the fundamental parameters of processing speed, working memory capacity, and knowledge bases which determine individual learning and performance behaviors. Advances in cognitive psychology and the availability of microcomputers make possible a breakthrough in the state-of-the-art of ability measurement. Studies will identify and measure individual differences in parameters relating to procedural and factual knowledge bases, working memory capacity and information processing speed. A primary goal is to determine how such parameters interact to account for individual differences in learning and performance behaviors. In particular, the role of processing speed in modeling learning and performance in high information flow environments will be studied. Identifying and measuring working memory capacity is another important topic.

2. Mental Workload and Brain Activity (RO 1.2.3): This research uses non-invasive techniques to record the electrical potentials and magnetic fields generated when large populations of neurons are active synchronistically. These techniques allow the brain's activity to be monitored as an individual performs specified tasks. The research attempts to elucidate the stages of information processing and allocation of mental resources during work tasks. This work also helps identify what parts of the brain are involved in particular mental functions.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAM:

a. Provide a theory-based system of ability measurement to improve the Air Force personnel selection and classification system.

b. Provide new approaches to training matched to human capabilities.

3. Improve the design of equipment and operational procedures so that the workload of demanding tasks such as flying tactical aircraft can be matched to human mental characteristics and capabilities.

SUBAREA 1.1 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 1.1 ($K)
2313T1	Manpower Management	576	576
	TOTAL		576

AFOSR Focal Point: Dr. J. F. Tangney
Telephone: (202) 767-5021

TECHNICAL AREA: Life Sciences

SUBAREA NUMBER AND TITLE: 1.2 Information Processing

GENERAL OBJECTIVES: The skilled performance of human operators such as military pilots requires effective use of the eyes, ears, and brain to extract information from the environment, analyze that information, and use it to guide the operator's actions. By supporting research on the mechanisms of sensory information processing, this program generates knowledge that can be used to select and train individuals appropriately for jobs in which sensory skills are important. This knowledge will also provide better ways of displaying visual and auditory information to match instruments optimally to human characteristics. It should also suggest new approaches to designing machines that can interpret visual scenes or recognize speech. Other parts of this research area address the nature of cognitive skills used in performing demanding tasks such as those encountered in military aviation. For example, better understanding of the nature of mental workload will allow better design of equipment and operational procedures. Noninvasive recording of brain activity may in time provide means of monitoring the mental status of individuals performing real-world tasks.

RESEARCH EFFORTS:

1. Visual Processes (RO 1.2.1): This research attempts to describe, quantitatively, the capabilities and limits of the human visual system in complex, dynamic environments. We are studying the relationship between stimulus and their encoding by basic sensory mechanisms. Essential factors include spatial and temporal interactions, perception of patterns, and the effect on visual perception of memory, attention, expectations, the other senses, and eye movements. We are also studying how visual attention is switched back and forth among stimuli and how attention is allocated during performance of multiple tasks. Formal analysis procedures are employed to develop models of the human visual system as it functions under real world conditions. These mathematical descriptions of human visual processing will be adapted to develop machines capable of image analysis.

2. Auditory Pattern Recognition (RO 1.2.1): See FY 86 Initiative.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Provide basic information on sensory and perceptual processes to improve selection and training of individuals and operational procedures.

b. Specify visual and auditory characteristics required to match machine displays optimally to human capabilities.

c. Suggest new research approaches to the design of machines capable of analyzing visual images or recognizing speech.

SUBAREA 1.2 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 1.2 ($K)
2313A5	Visual Processes	2800	2600
2313T3	Perceptual Dimensions of Pilot Behavior	293	293
2313V2	Visual Information Processing in the Fovea and Periphery	425	425
2312V3	Auditory Information (FY 86 Initiative)	210	210
2312W4	Multisensory Integration in Spatial Localization	30	30
2313A4	Biocybernetics/Workload	1325	1325
2312A6	Cognitive Processes	838	838
2313V1	Fundamentals of Man-machine Integration	306	306
	Total		6227

AFOSR Focal Point: Dr W O Berry
Telephone: (202) 767-5021

TECHNICAL AREA: Life Sciences

SUBAREA NUMBER AND TITLE: 1.3. Aerospace Physiology

GENERAL OBJECTIVE: This program attempts to elucidate the biological bases of skilled human performance. One part of the program emphasizes neural mechanisms that determine the state of responsiveness of the organism, especially aspects such as vigilence, attention, sleep-wake cycles, jet-lag, and fatigue. Another part of the program explores the neural mechanisms of learning and memory and attempts to relate them to new approaches to intelligent machine architectures. The knowledge generated should open ways of enhancing the skilled performance of individuals performing difficult tasks under stress.

RESEARCH EFFORTS:

Bioreactivity (RO 1.3.2): This effort focuses on the molecular and cellular mechanisms by which neurons respond to their synaptic inputs and by which the activity of large populations of neurons is tuned and coordinated. These mechanisms include the synthesis and release of neurotransmitters; activation of receptors, second messengers, and ion channels; and nonsynaptic transmission through electrotonic coupling and neurohumoral action. Studies linking events at different levels of organization (e.g. molecular, cellular, and behavioral) are particularly encouraged. The behavioral implications of neural regulation will be emphasized in FY86 and beyond. Sensorimotor integration in the cerebellum will be examined with both neurophysiological and neurochemical approaches.

Adaptive Networks (RO 1.3.1): Changes in cellular excitability will be studied directly in single nerve cells, cell culture, brain slices and animal models. These studies will include assessment of electrical activity within cells and across the cell membrane. The roles of positive and negative reinforcement in neuronal adaptation and goal seeking behavior in higher-level organization units in the nervous system will be explored. Actions of large nerve cells nets, the functions of major nuclei in the brain on information transfer and the specific localization of information passing pathways, will be investigated. Studies will be extended to provide a closer link between adaptive network modelers and neurobiologists collecting data upon which the models are supposedly based.

APPLICATION TO AIR FORCE PROGRAMS:

a. Enhancement of skilled human performance and utilization of complex machine systems.

b. Novel approaches to developing smart computers.

SUBAREA 1.3 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 1.3 ($K)
2312A2	Bioreactivity: Regulation of Neuronal Responsiveness	2800	2800
2312W2	Neurophysiology of Sensory and Motor Systems	170	170
2312W3	Neurochemistry of Sensory and Motor Systems: Local Circuit Chemical Interactions	173	173
2312A1	Adaptive Neural Networks	1500	1500
2312R1	Adaptive Network Architectures	370	370
	TOTAL		5013

AFOSR Focal Point: Lt Col C.T. Lind
Telephone: (202) 767-5021

TECHNICAL AREA: Life Sciences

SUBAREA NUMBER AND TITLE: 1.4 Bioenvironmental Hazards

GENERAL OBJECTIVE: Air Force operations cause the release of physical and chemical agents that may be harmful to Air Force personnel, the surrounding populace and the environment. National policy requires that the impact of all operations be assessed and controlled to the extent necessary to prevent degradation to health and the environment. Data and methods are needed to assess, measure and control Air Force generated chemical and physical agents to meet national standards while maintaining operational flexibility. An understanding of the fundamental interactions of these agents with biological systems and their actual mechanisms of action is required to provide effective means of protecting man and the environment against the hazards posed by Air Force generated physical and chemical agents.

RESEARCH EFFORTS:

1. Toxicology (RO 1.4.1): Provide fundamental data on toxic effects and elucidate mechanisms of toxic action of Air Force utilized chemicals. Devise novel methodologies to predict, detect, quantify and modify the toxicological hazards of compounds associated with Air Force weapon systems and operations in order to protect personnel from health and performance degradation. Areas of research currently supported include the role of chemical exposure in altering gene expression, toxicant-cell membrane relationships, chemically induced alterations in specific immune functions, and regulation of xenobiotic metabolism utilizing cytochrome P450 genes in directing the metabolism of toxic chemicals toward innocuous pathways. Research on the mechanisms of solvent neurotoxicity seeks to integrate behavioral, morphologic, and biochemical approaches toward the understanding of the cellular basis of solvent neurotoxicity.

2. Electromagnetic Radiation Bioeffects (RO 1.4.2): Determine the biological effects of exposure to Air Force generated electromagnetic radiations (EMR) from both pulsed and continuous wave sources. Research is conducted to determine the fundamental mechanisms of action of electromagnetic radiation on living tissue.

3. Chemical Environmental Fate and Effects (RO 1.4.3): Evaluate the environmental fate and biological effects of Air Force pollutants in aquatic and terrestrial ecosystems. Investigate ecosystems and develop models for prediction of real-world responses to Air Force environmental problems. Define the nature of chemical perturbation of the environment through theoretical and empirical studies.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Develop model systems for predicting toxic effects and environmental impact.

b. Develop novel biological techniques for detoxifying chemical agents.

c. Develop effective means of protecting man and the environment against the hazards posed by AF generated physical and chemical agents.

d. Promote operationally realistic exposure criteria.

e. Develop new, less toxic fuels and propellants.

SUBAREA 1.4 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 1.4 ($K)
2312A5	Environmental Toxicology	2550	2550
2312V1	Toxicologic Mechanisms of Air Force Chemicals and Materials	198	198
2312W1	Electromagnetic Radiation Bioeffects	737	737
	TOTAL		3485

AFOSR MANAGER: Dr Horst R Wittmann
Telephone: (202) 767-4985

TECHNICAL AREA 2: Materials

INTRODUCTION

The Air Force research program in materials covers research in structural and electromagnetic materials.

Research on structural materials encompasses the study of materials used for airframes, engines, and spacecraft; addresses the composition and microstructure of metal alloys, and ceramics; and covers the synthesis and characterization of composite polymers and glasses. The aim is to understand the properties of ambient and high temperature metal alloys and the modifications caused by forming and fabrication processes. Research in ceramics is largely concerned with improving fracture toughness. The polymer and glass research investigates the potential for combining compositional components in new ways.

Research on environmentally resistant materials pursues studies in the fundamentals of corrosion, abrasion, and radiation of nonelectronic ceramics, metals, polymers, and composites. Emphasis is on exploring the surface phenomena of these materials, and developing coatings to improve their resistance to hostile environments. A major portion of the research is devoted to non-destructive ways to evaluate the integrity of these protective materials.

The electromagnetic materials research emphasizes the synthesis and characterization of compound semiconductors for signal processing electronics, optical communications, sources and detectors, and microwave power generation and amplification.

Also included here is manufacturing research which provides basic knowledge for increasing the productivity of sophisticated aerospace systems through improved manufacturing techniques. Research on mechanical part formation is augmented with research on flexible robotic assembly.

FY 86 PLANNED FUNDING:

SUBAREA NUMBER	TITLE	FUNDS SPTG SUBAREA ($K)
2.1	Structural Materials	10310
2.2	Environment Resistant Materials	3172
2.3	Electromagnetic Materials	12040
2.4	Fluid, Lubricant, and Containment Materials	845
2.5	Nondestructive Evaluation	1174
2.6	Manufacturing Research	4000
	TECHNICAL AREA TOTAL	31541

AFOSR Focal Point: Dr. Alan H. Rosenstein
Telephone: (202) 767-4933

TECHNICAL AREA: Materials

SUBAREA NUMBER AND TITLE: 2.1 Structural Materials

GENERAL OBJECTIVE: Structural materials in use today are operating at or near their capacity with regards to stress, temperature and environment. Yet, it is necessary to prolong use of current systems, and to envision new ones which will demand lighter weight structures of extreme reliability and resistance to environmental attack or sudden failures. Progress toward development of a rational basis for creating or improving material systems (such as alloys, polymers, glasses, ceramics and composites) can be attained through understanding of the principles that govern properties and behavior as a function of microstructural features, composition, and processing parameters. Failures or degradation due to creep, fatigue and fracture are, in most cases, intimately related to the microstructures of materials. Understanding of these processes and the governing mechanisms must be integrated with appropriate macroscopic description by use of general constitutive equations of mechanics. It is anticipated that considerable progress can be achieved in structural reliability and integrity as a result of some basic studies which attempt a combined materials/mechanics viewpoint. (Subareas with related ROs: 2.2, 2.5, 2.6 and 4.1).

RESEARCH EFFORTS:

1. Structural Materials Design (RO 2.1.1): To establish the fundamental basis of methodology to provide comprehensive and systematic improvement of existing materials and development of new materials. To understand and explain mechanical properties of materials and their fundamental relationship to microstructural, compositional and processing variations.

The principles underlying phase decomposition processes and the influence of processing methods on the microstructure and properties of titanium alloys will be investigated. Research programs will seek to understand and develop powder metallurgy and rapid solidification techniques such that methods of producing aluminum alloys with improved mechanical properties may be established. Particular emphasis will be given to the production and compaction of powders, thermomechanical processing of the compacts, and aluminum alloys with high modulus/density ratios. A duplex microstructure will be developed for high strength aluminum alloys to achieve improved high and low cycle fatigue resistance. Additional research will provide fundamental information required to guide the design of new aluminum alloys with desirable intermediate temperature mechanical properties. Interfacial energies and coarsening rates of strengthening dispersoids will be studied and related to deformation and fracture resistance in these alloys. Quantum mechanical approaches will be used to develop an understanding of the effect of alloy chemistry on the bond strengths, mechanical properties and phase stabilities of advanced materials which normally possess limited ductility and fracture toughness.

2. Polymer Science (RO 2.1.2 and 2.1.3): To obtain scientific knowledge of polymers, polymeric compositions, and composites that will result in new plastic and elastomeric base materials for the development of structural and ablative composites, sealants, seals, transparent inner layers, adhesives, and coatings. To obtain fundamental knowledge to elucidate molecular and morphological structure and physical, mechanical and chemical property relationships in polymers and glasses.

The ordering phenomena of polymer fluids, ordered polymers and molecular composites will be investigated. A variety of new, high molecular weight rigid and semirigid chain polymer solutions within the set of polycondensations that provide benzothiazole, benzoxazole, benzimidazole, quinoxaline, and phenomaxazine repeat units will be synthesized. Experiments will be conducted to support the hypothesis that polymerization of these rigid systems in the anisotropic phase gives significantly higher molecular weights than polymerization in the isotropic phase. The sequential structural states and phase transformations leading to the formation of solids from rigid-rod polymer solutions (from the molecular to the micron size scale) will be investigated.

Theoretical relationships between structural and physical properties and morphology in liquid crystalline polymers, rigid chain polymers and glassy polymers will continue to be addressed. Research will continue in defining the quantitative relationships between time-dependent creep factors, structural variables and volume of rubbery and glassy polymers networks. The newly developed mean theory of polymer blends will be examined theoretically and experimentally for predicting miscibility in homopolymer, copolymer and terpolymer blends.

A semi-empirical molecular orbital approach will be developed to calculate properties of a wide variety of chemical compounds which may then be used to tailormake new polymeric materials. Research will continue on polymer structure-property correlations to understand cure processes and resulting mechanical properties. The fundamental parameters of glassy state cure processes will be investigated to discover higher temperature, processable polymeric materials. Research will continue on rigid rod and extended chain ordered polymer systems, with emphasis on the morphological effects and mechanical property advantages to be obtained from molecular composites. The structure and properties of aromatic-heterocyclic polymers, ordered polymer systems, reactive oligomers, and high glass transition temperature polymers for improved thermosetting and thermoplastic resins will be investigated.

3. High Temperature Materials (RO 2.1.4): To find new approaches leading to higher strength, thermodynamically stable, oxidation resistant, structural materials capable of reliable sustained operation in high temperature environments. To obtain a basic understanding of ceramics, nickel alloys, refractory alloys, titanium alloys and aluminum alloys with impoved elevated temperature performance, including those alloys resulting from rapid solidification and powder metallurgy techniques.

The key factors controlling crack initiation, subcritical crack growth and unstable fracture in single crystal nickel-base superalloy blade materials

will be identified and modeled. Anisotropy, strain localization, microstructure, and multiaxial applied stress states will be investigated with respect to micromechanical fatigue and fracture mechanisms. The role of alloy chemistry and microstructure on fatigue crack propagation processes at elevated temperatures will be studied in polycrystalline superalloy materials. The basic mechanisms of consolidation of superalloy powders during hot isostatic pressing (HIP) will be investigated. The research will examine the kinetics of superalloy powder consolidation and evaluate the effects of powder size, morphology and size distribution as well as HIP temperature, pressure and time. Research will be performed to improve the temperature capability and reduce the weight of gas turbine engine materials. Emphasis will be placed on understanding the effects of alloying additions, heat treatment and crystal structure on the room and elevated temperature strength, ductility and creep behavior of advanced ordered intermetallic compounds.

Research will focus on the role of whisker and continuous fiber reinforcement of ceramic matrices. In particular, the relative effectiveness of whiskers versus continuous fibers for producing tough composites will be evaluated. Magnesium aluminosilicate and aluminosilicate matrix composites will be pursued and will be produced from organometallic precursors. Selected matrices will be reinforced with partially stabilized zirconia to determine the effects of a toughened matrix on composite properties. The interrelationships of matrix chemistry, composite processing, microstructure, and mechanical properties will be studied. Nicalon SiC fiber will be coated with a variety of materials (e.g., BN, Si_3N_4) to vary the chemistry and bonding at the interface and study the effects of coating on stress corrosion, mechanical properties and interfacial shear strength.

The latest techniques of ultrastructure processing which include solution ceramics, sol-gel processing, organo-metallic synthesis and submicron particle synthesis will be used to produce novel composites. The sol-gel processing of composite amorphous and crystalline matrices will be investigated to ascertain the relative merits of the new drying chemical control agents (DCCA). The discovery of how to maintain dispersions of submicron powders within the sol-gel during gelation and drying will be applied and related to silicon carbide sol-gel composites. Micromorphology processing will build on the developed framework for electrochemical reactions at oxide-water interfaces. The new chemical cross-linking agents for polysilastyrene, and other polysilanes will be investigated. The functional range for polymer cross-linking agents for polysilastyrene, and the pyrolysis necessary to achieve reinforcement within porous gel matrix composites, will be addressed. Research to provide producible and reliable microstructures, controlled size and distribution of pores and minor phases, and controlled compositions will be pursued. Fundamental understanding of particulate formation and surface chemistry will be combined with the development of theoretical models for processing, including critical experiments with model ceramics to test the generalization for controlling the pre-sintered structure, sintered microstructure and ultrastructure. This research will include chemical and polymeric synthesis and processing of covalent powders and multication multiphase silicates.

The mechanical and thermal stability of low expansion silica and silica-titania sol-gels utilizing ultrasonic methods based upon pulse

superposition will be investigated. Models derived to explain the properties of thermoset polymers will be extended to understand ceramics derived from organometallic polymers. Work will be continued on noncomposites, nanocomposites, tripitasic or diphasic gels on a 1-10 nm scale which are mechanically tough. New organic-inorganic preceramic polymers will be investigated.

4. Materials Behavior (RO 2.1.5, 2.1.6, 2.1.7, 2.1.8, 2.1.9 and 2.1.10): To model fundamental metallurgical factors which govern crack initiation and progagation phenomena in structural materials that experience plastic flow prior to failure. To determine mechanisms of subcritical crack growth and crack initiation and propagation (under variable cyclic stressing), and the relationship of intrinsic and extrinsic variables on these mechanisms. To describe and explain flow and fracture mechanisms at elevated temperatures. To obtain fundamental knowledge of the effect of chemical, electrochemical, mechanical and metallurgical influences (and interactions) on the load-bearing capability of structural materials. To obtain fundamental understanding of the response of aircraft and propulsion materials to high rates of applied mechanical loading and thermal impulse.

The mechanical property-microstructure-alloying relationships will continue to be investigated as related to the fatigue resistance of powder metallurgy and wrought alloys being considered for aerospace structural applications. The interrelation between fatigue crack growth rate and plastic zone characteristics, and the way in which environment, temperature and load history alter the plastic zone characteristics, will be determined. A systematic study will be undertaken to determine the high temperature deformation, recrystallization and grain growth behavior of two phase titanium alloys. Research will identify mechanical, microstructural and environmental factors governing the (near threshold) fatigue crack growth of long and short cracks in wrought and powder aluminum alloys, single and polycrystalline superalloys and advanced aluminides. The effect of frequency, temperature, stress ratio and stress intensity range will be examined. Investigations of hydrogen related mechanisms of stress corrosion cracking phenomena will be continued. The importance of grain size, grain size distribution and phase morphology in influencing the fatigue crack propagation behavior of powder metallurgy, hot isostatically pressed, nickel-base superalloys will be assessed, including the effect of overloads, variable loading history, and short cracks. Research is continuing to define those conditions where static fracture mechanics concepts apply to fracture of structural materials under dynamic loads, and indicate how classical fracture mechanics can be modified to apply to short-duration pulse loads. Additional research will aim at understanding the effect of flaws (size and geometry) on the mechanical properties (toughness) of advanced ceramic materials.

5. Failure Mechanisms of Filamentary Composites (RO 2.1.11): To determine the relationship of fiber, matrix, and interface characteristics to gross mechanical properties such as stiffness, strength, and toughness in filamentary composites. Relate initiation and growth of defects, due to local damage state development and residual stress to life and strength degradation through analytic models consistent with established principles of mechanics.

Double cantilever beam tests will be utilized for resin and unidirectional composite characterization. The edge delamination specimen with a starter crack will be applied to composite laminates. Stress analysis models, based on higher order laminated plate theory, will ascertain the effect of specimen geometry on energy release rates. The models will also allow the energy release rate approach to be compared to a failure requirement such as the average stress criterion. Both static and fatigue loading will be considered for graphite/epoxy materials and graphite/thermoplastic materials. Failure modes will be characterized. The end notched flexure test will be utilized to analyze resin and unidirectional composites. Edge delamination specimens with starter cracks will be applied to laminates. Stacking geometries will be chosen such that combinations of Mode I compression/Mode II and Mode I tension/Mode II can be examined and compared against results obtained from off-axis center-crack specimens tested in both tension and compression. Research will be aimed at understanding the synergistic interactions between strengthening precipitates in the matrix and mechanical behavior of SiC/Al composite materials.

Impact behavior of composites will be studied. Attempts will be made to identify damage initiation parameters and to separate material effects from structural effects (boundary conditions, etc). Delamination-buckling models will be utilized for parametric studies to relate structural behavior to material behavior.

Detailed quasi-static and fatigue damage state development will be investigated in gradient fields using laminates with a central hole, employing vibrothermography and other techniques, to identify mechanisms of stress redistribution. Delamination crack-tip damage process zone development will be studied using a loading stage in a scanning electron microscope to capture real time, in situ damage processes as a basis for damage modeling. Post-cure laminate residual stresses will be studied to determine the nature and significance of residual stresses in subsequent mechanical loading and initial residual stress induced damage.

6. Life Predictions for Materials (RO 2.1.12): To describe the interrelationship between material features on the microscopic scale and gross behavior as described by solid mechanics through general constitutive equations and fracture mechanics. To develop a life prediction methodology that can determine residual strength and life expectancy, lead to accelerated testing design criteria to avoid damaging stresses during the life of structures, and provide means to guarantee safe life for a given usage.

Life prediction models will be developed for materials with initial defects using fracture mechanics methodology. Effects of short cracks, stress concentrations, and environment (for internal defects) will be evaluated for titanium alloys and titanium aluminides. Threshold stress intensity concepts will be used to predict stress levels for runout in high cycle fatigue. Detailed crack tip deformation fields will be investigated using high resolution in-plane and out-of-plane interferometry and using inelastic finite element analysis to investigate the validity of current crack growth criteria. Effects of environment on crack growth will be determined from experimental investigations on superalloy single crystals, titanium aluminides, and Rene'80. Thermo-mechanical fatigue crack growth tests will be

conducted and tensile, creep, and crack growth tests will be performed in vacuum, laboratory air, and in molten salt. Results will be consolidated into a mechanistically based model for life prediction under non-isothermal conditions.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Obtain new and improved airframe, engine and spacecraft structural materials of higher strength and toughness to permit design of lightweight and/or stiffer structures and allow for greater system performance characteristics.

b. Develop lightweight turbine blade and static structure materials possessing improved strength, creep and stress rupture characteristics for advanced turbine engines. Develop materials systems requiring less usage of strategic elements.

c. Obtain lightweight, inexpensive, oxidation resistant, very high temperature ceramic engine components that can operate without complex cooling air requirements in turbine engines and various forms of advanced power generators.

d. Develop high temperature polymeric materials as resins for the fabrication of structural composites and for use as structural adhesives.

e. Provide a predictive property methodology for design of new polymers and glasses rather than the traditional empirical approach commonly employed.

f. Reduce critical and costly processing problems of advanced non-metallic materials.

g. Provide a rational basis for the development of improved adhesives and adherent surface treatments leading to more reliable, longer lasting adhesively bonded structures.

h. Reduce life-cycle costs of AF systems through control of corrosion and stress corrosion.

i. Increase reliability, predictability, longevity and safety of airframe and engine structures.

j. Upgrade criteria for structural design, minimize unanticipated failure, and implement a damage tolerant design philosophy.

k. Increase survivability and predict response of materials in aircraft components (such as fan blades) subjected to foreign object damage.

The ability of structural materials to meet the cost, performance, reliability and durability requirements of aerospace weapons systems is critical to the future development of advanced systems. The improved understanding of the relationships between the compositional and microstructural features of metals, polymers, and ceramics and their physical, chemical and mechanical properties; application of this knowledge to the improvement of the properties of available materials; and the design of new candidate materials to meet the requirements of the Air Force will be addressed by this research.

SUBAREA 2.1 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 2.1 ($K)
2302B2	Structural Durability	3443	346
2302P1	Life Prediction of Engine Materials	1050	1050
2302P2	Failure Mechanisms and Mechanics of Composites	570	570
2303A3	Structural Chemistry	4695	1365
2303B2	Chemical Reactivity and Synthesis	2905	1085
2303Q3	Polymer Research	1790	1790
2306A1	Metallurgy of Structural Materials	2384	2199
2306A2	Environment Resistant Materials and NDT	1907	913
2306P1	High Temperature Materials	413	413
2306P8	High Temperature Ceramic Composites	579	579
	TOTAL		10310

AFOSR Focal Point: Maj J. W. Hager
Telephone: (202) 767-4933

TECHNICAL AREA: Materials

SUBAREA NUMBER AND TITLE: 2.2 Environment Resistant Materials

GENERAL OBJECTIVE: Aerospace system components are subjected to a variety of harsh environmental conditions such as high temperature, oxidizing atmospheres, mechanical erosion, chemical corrosion, laser interactions, and conventional and nuclear weapons effects. In this subarea, we are studying material degradation mechanisms in various environments, the mechanisms of protection afforded by surface layers and new materials which are inherently more resistant to environmental degradation. Specific research includes work on novel surface interogation techniques, laser-material interactions, fundamental thermophysical properties and phase stability of high temperature materials, and new synthesis and processing methods for ceramic materials. All materials (including polymers, metals, ceramics and composites) except those for electronic applications are included in this subarea. (Subareas with related RO's 2.1, 2.5, 4.1, 5.1, 5.2, 5.3).

RESEARCH EFFORTS:

1. High Temperature Environment Resistance (RO 2.2.1):
We are supporting work to develop or improve ceramic processing techniques to provide the longer life, higher strength and improved reliability required to make ceramics viable in the gas turbine environment up to 4000°F. We envision that materials will consist of oxide and nonoxide ceramic-and carbon/carbon-composites. The purpose of our funded work is to design the molecular structures and chemical processing routes which will lead to matrices whose interfacial and surface chemistries are understood and predictable. This is essential to understanding fiber-matrix reactions and microstructure which will ultimately determine strength, toughness and durability of composite materials in the turbine environment. We are funding research in five major areas to support these objectives: (a) preparation and properties of well defined inorganic and organic colloids; (b) inorganic and organic coatings of fine particles; (c) surface modifications of colloids by chemical means; (d) experimental and theoretical studies of particle-particle interactions in single and mixed systems; (e) experimental and theoretical studies of particle/plane interactions (adhesion).

We are also interested in the high temperature thermophysical properties and phase equilibria of candidate components of ceramic composites. Because of the sheer number of permutations, it is not practical to collect empirical data on all the systems of interest over the entire range of interest. We are therefore funding work to develop phase equilibrium models which can either be used to predict phase equilibria from fundamental principles, to make sense of conflicting data or to extrapolate known data. Precise data on heat capacities, heats of transformations and transformation temperatures are essential to the reliability of these models.

2. Ambient and Low Temperature Environment Resistance (RO 2.2.2):
Materials degradation almost always begins at its interface with its environment. We are therefore directing work to determine structure orientation, composition, and reactivity of surface molecular species which form when metal surfaces are treated with chemical compounds. The modification of such surfaces will be studied to account for their unique behavior. A new 'in situ' technique for determining changes in weight occurring at an electrode/solution interface will be used to study growth of oxide films on noble metals.

We also seek to investigate the corrosion related processes which occur during the adsorption and desorption of oxygen and other corrosive species on metal surfaces, to conduct theoretical and experimental studies of how protective layers on various surfaces withstand corrosion attack, to develop techniques to investigate positions and characteristics of adsorbed species and to observe reactions of adsorbed corrosive organic species on surfaces. New concepts for protective systems are being investigated. Scanning vacuum tunneling microscopy is being explored as a technique to determine surface structure of metals and adsorbed spectroscopy will be developed as a tool for both surface adsorbate detection and desorbate study.

3. Thermochemical Environment Resistance (RO 2.2.4):
In this research objective we seek to develop materials suitable for resisting penetration of high energy laser irradiation in space environments. We are funding work to study materials which promise high temperature resistance, light weight, and unique performance mechanisms under high power laser irradiation in a vacuum. We also want to determine if materials which are effective in a vacuum can be made to perform in the atmosphere and vice versa. Research is underway to study high energy laser interactions with materials with regard to their mechanisms of protection, to develop mathematical descriptions of the energetic interactions, and to quantitatively describe vaporization and condensation phenomena from a chemical physical point of view.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Reduce corrosion on aircraft and provide effective, low cost surface protection processes and coatings.

b. Reduce high temperature oxidation of superalloys in turbine engines.

c. Develop ceramic composites for high temperature applications in gas turbine engines to increase the operating temperature and thereby improve the efficiency (thrust to weight ratio and the specific fuel consumption).

d. Provide new structural materials for hypersonic and transatomspheric vehicles.

e. Develop high temperature materials for advanced space power systems.

f. Harden structural materials against laser damage.

SUBAREA 2.2 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 2.2 ($K)
2303A1	Chemical Techniques	1303	255
2303A2	Surface Chemistry	1963	1105
2303A3	Structural Chemistry	4695	1000
2306A2	Environment Resistant Materials and Nondestructive Evaluation	1907	252
2306C4	Spacecraft Survivability	1240	560
	TOTAL		3172

AFOSR Focal Point: Capt. Kevin J. Malloy
Telephone: (202) 767-4931

TECHNICAL AREA: MATERIALS

SUBAREA NUMBER AND TITLE: 2.3 Electromagnetic Materials

GENERAL OBJECTIVE: This subarea encompasses a broad spectrum of research objectives that relate to the synthesis, preparation, characterization and analysis of electromagnetic materials. These efforts normally include detailed understanding and control of material purification, film and crystal growth, defect structure, selective and controlled doping, and related processes and phenomena. The materials are generally in the condensed state, either crystalline or amorphous in form. In view of their potential impact on new and improved electronic and electro-optic components and aerospace systems, improved understanding of the basic mechanisms responible for their semiconducting, optical, thermal, acoustic, magnetic, superconducting and insulating properties is needed as a foundation for the evolution of novel and advanced device concepts. These devices utilizing the special properties and characteristics of advanced electromagnetic materials could have a profound influence on the Air Force's ability to carry out its reconnaissance and surveillance, navigation and guidance, command, communication, control and intelligence and electronic warfare responsibilities and functions. (A subarea with related ROs is 7.4).

RESEARCH EFFORTS:

1. Synthesis, Growth and Preparation (RO 2.3.1): We seek the development of bulk and epitaxial thin film compound semiconductor growth processes for millimeter wave and signal processing applications. Gallium arsenide and indium phosphide and their related alloys are of particular interest. Also of concern is the growth and processing of fiber and integrated optic materials for use in optical communications and signal processing. The interest in these materials is due to their radiation hardness, optical transparency, frequency stability and magnetic and magneto-optical properties.

2. Characterization of Properties and Constituents (RO 2.3.2): The emphasis here is on both the application of existing techniques for characterizing and analyzing the special properties of electromagnetic materials and on the development of new techniques for studying these materials. Particularly relevant are the electronic properties as related to the transport of carriers in electromagnetic materials, the optical and acoustic properties affecting the signal processing applications, and the magnetic properties. The study of defects such as imperfections and impurities in these materials has proven to be of particular importance in understanding the properties of electromagnetic materials.

3. New Methods and Techniques (RO 2.3.3): As can be seen from the previous descriptions, the continued development of new techniques is crucial to our goals for the growth and characterization of electromagnetic materials. We are doing work on predicting the properties of these materials. Of particular importance this year is the development of fundamental and innovative approaches to the growth of thin films for optical and electronic applications. This includes not only new thin film growth techniques, but also new means of characterizing thin films. The latter objective is being met by increased emphasis on optical characterization techniques and spectroscopies.

4. Optical Materials (RO 2.3.4): We are investigating not only the basic optical properties of materials such absorption and reflectivity, but also the nonlinear phenomena associated with solid state polymers. Many signal processing applications exist for these types of materials. The growth of optical thin films is examined with emphasis on improving the microstructure for higher laser damage thresholds. Efforts are continuing to develop semiconductor based detectors of infrared light in both the III-V and silicon materials systems. Here, we seek low noise, sensitive and fast detectors.

5. Microwave Materials (RO 2.3.5): Efforts here are centered around the semiconducting III-V compounds previously discussed and on low work function cathodes for traveling wave tubes. The latter efforts involve examining the basic chemical and physical factors affecting the control, activation, lifetime and poisoning of various types of these cathodes. Also of interest are the phase transition materials that exhibit changes from metallic to insulating conductivity.

6. Semiconducting Materials (RO 2.3.6): In the area of conventional semiconductors, efforts involve the investigation of low dislocation density, large diameter gallium arsenide substrate materials for improved millimeter wave device applications. Other objectives described above have considerable overlap in this area. Efforts in novel semiconducting materials include solution grown silicon carbide and research on copolymers and composites of structural and conducting polymers. We seek understanding of the mechanisms of electrical conductivity in doped and undoped polymeric semiconductors.

7. Superconducting Materials (RO 2.3.7): Efforts are aimed at obtaining superconducting materials with higher transition temperatures, higher magnetic field capabilities and higher current carrying capabilities. These materials will have use in signal processing devices and in high field magnets.

8. Interfaces and Surfaces (RO 2.3.11): Understanding the chemical and physical factors that affect and control thin film and epitaxial growth are investigated for metals, dielectrics and semiconductors. The characterization of the fundamental electronic processes that occur at surfaces and interfaces of these materials are examined for spectroscopic and device purposes.

9. Radiation Hardened Materials (RO 2.3.12): Research is conducted into the synthesis, growth and characterization of radiation hardened ferroelectric and piezoelectric materials for frequency and time applications.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. High performance long wavelength infrared detector arrays for low background space environments which operate at higher temperatures with increased radiation hardness.

b. Substantially reduce the cost of millimeter wave transmit/receive modules for phased array radars.

c. Higher power and more efficient transit time devices such as GUNN, BARITT, TRAPATT, and IMPATT diodes for fuzing.

d. Reliable high transition temperature superconducting material for macro- and micro-applications for multimegawatt power conditioning and for microwatt signal processing.

e. Charge transfer signal processing devices.

f. Active and passive materials for optical communication.

g. Low loss fiber optical materials.

h. Optical communications and analog signal processing devices.

i. Optical phase conjugation and optical bistability for image and fast signal processing.

j. Oscillators for high frequency applications that are stable under ionizing radiation.

k. Better power, lifetime, costs, and efficiency of microwave devices of radar and command, control, and communication.

l. Parametric oscillators, up-converters, and polarizers for optical communications and laser radars.

m. Lower cost, high purity electromagnetic materials with unique electronic and electro-optical properties.

n. Optical and magnetic surface acoustic wave devices.

o. Technology to improve the performance and operating characteristics of III-V devices.

p. Improved materials for time and frequency standards.

q. Damage resistant optical materials for high energy laser applications.

r. Nonreflecting coatings for stealth aircraft.

s. Special materials with anisotropic electrical conduction, magnetic, insulator and semiconductor properties for novel electromagnetic devices.

t. Low work function cathodes for spaceborne travelling microwave tubes.

SUBAREA 2.3 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 2.3 ($K)
2301A8	Plasma Physics	3116	176
2303A1	Chemical Techniques	1303	150
2303A3	Structural Chemistry	4695	2330
2303B2	Chemical Reactivity and Synthesis	2905	215
2303Q1	Surface Phenomena	335	335
2305A9	Joint Services Electronics Program	2750	775
2305R4	Microwave Component Modeling	500	110
2306B1	Microwave Materials	1240	1240
2306B2	Novel Electromagnetic Materials	1687	1687
2306C1	Superconducting Materials	1906	1906
2306J1	Advanced Electromagnetic Materials	1091	1091
2306Q1	Electronic and Magnetic Properties of Materials	773	773
2306R1	Characterization of Semiconductor Device Materials	992	992
2306Y1	Optical Thin Film Coating Development	260	260
	TOTAL		12040

AFOSR Focal Point: Dr A. J. Matuszko
Telephone: (202)767-4963

TECHNICAL AREA: Materials

SUBAREA NUMBER AND TITLE: 2.4 Fluid, Lubricant and Containment Materials

GENERAL OBJECTIVE: The research in this subarea is aimed at providing fundamental scientific information and new concepts leading to improved functional fluids, lubricants, seals and sealants, and elastomeric containment materials. Research on the synthesis of new chemical systems will provide the approaches to obtaining these materials (reactants, routes, conditions and mechanisms for organic, semiorganic and inorganic reactions and polymerizations), as well as the basis for broader scope synthesis approaches in tailoring molecular structures and compositions to achieve unique combinations of properties. Work needed includes approaches to the synthesis of new intermediates, difunctional monomers, and multifunctional compounds which can be used to synthesize high polymer network structures with elastomeric

properties.These elastomers should exhibit broad temperature range viscoelasticity by virtue of their low glass transition temperatures and high temperature stabilities. New approaches are needed for the synthesis of silahydrocarbons and related compounds for broad temperature fluids applications. Research is needed on understanding basic principles and parameters governing the behavior of fluid and lubricant materials, including viscosities and bulk moduli, their dependence upon temperature and pressure, and their correlation with molecular structures.

RESEARCH EFFORTS:

1. Synthesis and Behavior of Functional Fluids and Lubricants (RO 2.4.1): Find synthesis approaches to new high molecular weight, low vapor pressure chemical systems molecularly tailored to lower flammabilities, increase stabilities, and broaden fluid ranges. Scientific information will be obtained on new synthesis approaches to future generation classes of chemical compounds which lead to nonflammable, wide temperature range fluid materials capable of withstanding future state-of-the-art use temperatures without significant degradative changes occurring over long periods of time. Continue the program on novel synthetic hydrocarbons selected from alkylaromatics and silahydrocarbon structures. Initiate a program on the synthesis of model compounds of chlorofluoroalkanes for providing the basic information on types of chemical structures required for nonflammable hydraulic fluids. Determine the mechanism by which various synthesized fluids interact under stress of thermal degradation and chemical interaction with various agents in particular those causing corrosion of metal. Such data on molecular structure/property correlations will provide guidelines for the synthesis of improved fluid materials.

2. Synthesis and Behavior of Elastomers (RO 2.4.3): Evaluate approaches to the synthesis of high molecular weight polymer seal and sealant materials specifically tailored in molecular structure. Scientific information will be developed on novel approaches to the synthesis of chemical systems newly conceived in molecular structures to exhibit exceptionally broad temperature

ranges of viscoelasticity by virtue of low glass transition temperature and long term stabilities greatly exceeding current capabilities. New approaches to synthesis will include the development of new fluorination techniques.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Provide fundamental information on new and improved functional fluids, additives and lubricant materials.

b. Provide thermo-oxidatively stable materials with exceptionally low glass transition temperatures for broad use in hydraulic system seals, fuel tank sealants, expulsion bladders, etc.

c. Provide fundamental information in regard to structure and synthesis of synthetic hydrocarbons, e.g., alkylaromatics and silahydrocarbon fluids for Air Force aircraft and missile hydraulic fluid systems requiring wide liquid range utility.

d. Provide fundamental knowledge on the synthesis and properties of chlorofluorocarbon materials for future nonflammable aircraft hydraulic fluid systems.

SUBAREA 2.4 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 2.4 ($K)
2303B2	Chemical Reactivity and Synthesis	2905	570
2303Q2	Fluids and Lubricants Synthesis	275	275
	TOTAL		845

AFOSR Focal Point: Major J. W. Hager
Telephone: (202) 767-4933

TECHNICAL AREA: Materials

SUBAREA NUMBER AND TITLE: 2.5 Nondestructive Evaluation

GENERAL OBJECTIVE: The mission of military aircraft demands high performance of very lightweight components - which implies that systems are designed with small margins of safety. Since material flaws can be catastrophic under such conditions, nondestructure evaluation (NDE) plays a major role in the production, operational safety and maintenance of Air Force systems. NDE began as an intuitive measurement art, but has become much more sophisticated as we seek to discover ever smaller defects. Furthermore, the system components cover the entire spectrum of materials used for large structural objects, gas turbine engine components and very large scale integrated circuits. The function-defeating flaw in a component varies in size from several centimeter long cracks to submicron defects. The flaws must be discovered both on the surface and deep within the bulk of the material. Given the extremely broad technical requirements of NDE, we fund investigations which promise to improve our understanding of the interactions of electromagnetic and elastic interogating signals with flaws and which attempt to discriminate between flaws and noise. The overall objective is to improve material integrity and reliability by improving the reliability of our flaw-detection capability, with the eventual goal of completely automated inspection. (Subareas with related RO's 2.1, 2.2, 4.1, 5.2).

RESEARCH EFFORTS:

1. Improved NDE techniques (RO 2.5.1):
In our effort to develop quantitative relationships between flaw size and shape and structural integrity of metals, ceramics, composites, and coatings, we are funding work on novel signal processing algorithms to separate flaw signals from clutter and to quantify flaw signals from ultrasonic NDE. Electromagnetic sensor arrays may have the capability to be used as proximity sensors for robot arms and hands and then be used in a "zoom" mode to look for surface flaws. We are supporting fundamental theoretical and experimental work with such arrays. To find and quantify the tiny flaws on large scale integrated circuits, magnetic storage media and laser mirrors, microscopic NDE approaches are needed. We are funding work on the use of cryogenic acoustic microscopy and laser optical microscopy to examine defects less than 1 micron in size.

We also seek to develop and experimentally verify theoretical models of ultrasonic wave propagation in anisotropic multiphase materials. Emphasis is placed on the description of propagation modes not used in conventional NDE testing such as plate modes in composites and the identification of features of these modes which are sensitive to material properties and defects which are not normally measurable. Advanced signal processing techniques are being investigated in order to identify and optimize those methods with the greatest potential for reproducibly isolating physically significant signals of

interest from both coherent and incoherent extraneous information. Research aimed at a long range objective of providing intelligent in-process quality assurance capabilities is also underway. We seek to combine advanced signal processing techniques with Artificial Intelligence to significantly increase flaw detection capability, quantify flaw sizes and reduce the dependency on humans in the interpretation of data.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Provide manufacturing and in-service inspection methods to allow safe and reliable use of metallic and composite materials and structures.

b. Refine accept/reject criteria for components.

c. Improve reliability of structural materials.

d. Enhance flaw detection capability in microelectronics, laser mirrors and storage media.

SUBAREA 2.5 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 2.5 ($K)
2306A2	Environment Resistant Materials and Nondestructive Evaluation	1907	742
2306P5	NDE Technology	432	432
	TOTAL		1174

AFOSR Focal Point: Maj J. W. Hager
Telephone: (202)767-4933

TECHNICAL AREA: Materials

SUBAREA NUMBER AND TITLE: 2.6 Manufacturing Research

GENERAL OBJECTIVE: This subarea includes a wide variety of processing science activities that are expected to lead to new or improved methods for the fabrication of metals, ceramics, organics, composites and electromagnetic materials or devices. It is becoming increasingly clear, however, that the efficient production of defense systems involves a great deal more than the design and development of effective fabrication processes. The methods by which these processes are controlled; the degree to which they can be automated; the extent to which adaptive learning can be introduced; and the flexibility of rescheduling to handle small batch lots are all important for the productivity of our defense industrial base. In this subarea we integrate a variety of disciplines to build the technology base for efficient manufacture of aerospace system components.

RESEARCH EFFORTS:

1. Processing Science (RO 2.6.1):

In this research objective we will continue to investigate superplastically formed titanium and aluminum alloys to better understand the mechanical properties and microstructural features resulting from this process. A better understanding of the dependence of superplastic strain rate on temperature, flow stress, grain size, cavity formation, and other microstructural details will contribute significantly in optimization of processing variables to enable material to be deformed at the highest possible forming rates. We are also funding work to develop analytical models for describing material behavior and for describing metal flow for 3-D nonaxisymmetric structures. The models are based on a rigid thermoviscoplastic finite element model for 3-D non-symmetric metal flow at large plastic strains which is being combined with an elastic-plastic finite element model. Physical modeling is used to validate analysis.

Processing microstructure maps and constitutive equations are being developed which illustrate how microstructure and defects evolve during deformation. Theoretical and experimental studies of hot workability are being conducted for P/M aluminum, nickel base alloys and titanium alloys.

2. Manufacturing Research (RO 2.6.2):

In one portion of this subarea we seek to identify the significant variables both physical and geometric, affecting the design of metal working processes. This information will be used to create knowledge representation schemes and problem solving methods for the inference engine of an expert system. Rule sets will be defined, and the expert system will be tested on problems with known solutions.

In a second portion of this subarea, we focus on innovative utilizations of artificial intelligence in NDE. We seek to creat AI algorithms which can analyze NDE data in its orginal 3-D form and cross-correlate information from different types of inspection. We will explore the feasibility of using AI expert systems to obtain quantitative information on localized flaws and spatially extended variations in material properties by combing data from different inspection methods.

The third portion of this subarea is concerned with robotics investigations. Here we seek to establish new concepts and approaches to provide non-linear adaptive control to extremely flexible robot arms, provide artificial intelligence approaches for both planning and obstacle avoidance, significantly advance the capability of computer-based object recognition, discover techniques to permit direct control from computer-based design data and create innovative automated approaches for automated discrete part assembly. Efforts to establish innovative techniques for vision and obstacle avoidance will be completed.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Reduce present long lead time on die delivery for aerospace forgings through increased accuracy of computer aided die design.

b. Improve performance of metal alloys through control of processing parameters.

c. Reduce cost of complex geometry structural components through greater understanding of forming and joining phenomena.

d. Lower production and refurbishment costs on medium size lots of aerospace assemblies through intelligent task automation of robotic assembly and inspection.

e. Decrease exposure of Air Force personnel to hot, heavy, hazardous, and repetitive labor through robotics.

SUBAREA 2.6 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 2.6 ($K)
2306A1	Metallurgy of Structural Materials	2348	185
2306A3	Manufacturing Sciences and NDE	1121	1121
2306P7	Processing Fundamentals	694	694
2306P9	Manufacturing Science	2000	2000
	TOTAL		4000

AFOSR MANAGER: Dr Donald L. Ball
Telephone: (202) 767-4960

TECHNICAL AREA 3: Geophysics

INTRODUCTION

Research requirements for geophysics technology describe special needs attributable to the interaction of Air Force systems with the environment.

Problems arise because the state of the environment is not static but varies due to solar activity, meteorological phenomena, earthquakes, nuclear weapon detonations, jet aircraft operations, etc. When these changes occur, Air Force systems and operations are frequently degraded. To avoid and to solve these problems, we must understand the physical world - either as it naturally exists or could exist. We must be able to precisely define the state of the environment in a specific area at a specific time; predict the occurrence, extent, and duration of disruptive variations; and describe the effects on systems.

This technical area is subdivided into five subareas: 3.1-Space Physics Research; 3.2-Optical/IR Environment Research; 3.3-Ionospheric Research; 3.4-Earth Science Research; and 3.5-Atmospheric and Meteorological Research. For each subarea, the areas of major thrust are as follows: 3.1--solar research and magnetospheric research; 3.2,--atmospheric transmission and optical/infrared backgrounds; 3.3--atmosphere composition and chemistry and ionospheric structure and coupling to the magnetosphere; 3.4--geodesy, gravity, earth motion, and seismology; and 3.5--global scale dynamics, meso-scale dynamics, and satellite meteorology. These technical subareas parallel the corresponding "Technology Thrusts" for the AFGL programs in exploratory development.

The following pages will detail the planned research for each of the technical subareas.

FY 86 PLANNED FUNDING:

MAJOR THRUST INITIATIVE:	FUNDING ($K)
MAPSTAR (Middle Atmosphere Periodic Structure Asssociated Radiance)	600
TOTAL	600

SUBAREA NUMBER	TITLE	FUNDS SPTG SUBAREA ($K)
3.1	Space Physics Research	5169.8
3.2	Optical/IR Environment Research	7376
3.3	Ionospheric Research	5894
3.4	Earth Science Research	2722
3.5	Atmospheric and Meteorological Research	3380
	TOTAL	24541.8
	TECHNICAL AREA TOTAL	25141.8

AFOSR Focal Point: Lt Col Gerald J. Ditlberner
Telephone: (202) 767-4960

TECHNICAL AREA: Geophysics

MAJOR THRUST INITIATIVE: MAPSTAR (Middle Atmosphere Periodic Structure Associated Radiance)

GENERAL OBJECTIVE: Air Force surveillance systems must detect targets in the presence of interference and cluttered backgrounds. In the infrared, some wave-like motions frequently give rise to periodic structures in emitted radiance, which is a potential source of such clutter. Sources of such motions must be comprehended, along with an understanding of wave propagation, frequencies, intensity variations, geographic occurrences, altitude dependence, and spatial extent.

RESEARCH EFFORT: A four year program will gather data, perform analyses and develop models of periodic infrared structure sources. A comprehensive data base will be gathered using mobile, ground-based units for maximum geographic flexibility and minimum cost. Several different kinds of instruments will be used simultaneously at different locations in coordinated campaigns for sensing several spectral signatures and geometrically triangulating sensed locations. Instruments include interferometers, scanning photometers, radiometers, radar, Fabrey-Perot units, spectrometers, intensified cameras/vidicons, all sky cameras and lidar. Multi-organizational participation is planned to provide a broad base of alternate approaches to analysis. Supporting analyses and modeling will be used to aid interpretation of results and to guide experimental pursuits. Where appropriate, laboratory experiments will support the effort.

FY 86 PLANNED FUNDING: $600K

AFOSR Focal Point: Dr Henry R. Radoski
Telephone: (202) 767-4906

TECHNICAL AREA: Geophysics

SUBAREA NUMBER AND TITLE: 3.1 Space Physics Research

GENERAL OBJECTIVE: The purpose of this research is to obtain an understanding of the significant environmental conditions that affect the survivability and reliability of satellite sensors and electronics as well as the propagation conditions for communications and radar systems. In order to meet this objective, research is required on solar-magnetospheric-ionospheric interactions, including research in the X-ray, EUV, optical and radio portions of the solar spectrum; measurements and theoretical studies concerning the Van Allen radiation belts to assess and predict long-lived contamination by nuclear debris; studies of the interplanetary magnetic field, the magnetosphere and the propagation of particles and waves; and finally, research on processes resulting from solar and nuclear inputs, both electromagnetic radiation and particles. Some understanding of all of these processes is needed, if one intends to determine environmental parameters of importance to the survivability of sophisticated, long-lived satellite systems and large structures in space.

RESEARCH EFFORTS:

1. Solar Activity Forecasting (RO 3.1.1): Research will be done in order to develop a capability to predict or forecast solar activity such as flares, which are responsible for geomagnetic disturbances in near-Earth space, for both long-range outlooks and short-range predictions. Processes of energy transport, heating and particle acceleration in solar flares will be studied. Observations will be made of changes in the solar corona and the contiguous interplanetary space environment over one complete 11-year solar activity cycle, and how these changes are propagated to, and produce effects on, the Earth. Recently-developed frequency-agile radio receivers and the world's largest radio telescope, the Very Large Array (VLA) will be used to observe and analyze pre-flare changes in radio-frequency solar emission. Coronal observations in several temperature regimes will be utilized to expand our knowledge and predictive capability. Automated systems to predict geomagnetic disturbances will be developed. The physics and geophysical effects of coronal mass ejections into interplanetary space will be studied. Solar electromagnetic emission that will influence the aerospace environment after the occurrence of a specific solar phenomenon will be described. Phenomena on the sun and in the interplanetary medium that are associated with specific perturbations of the aerospace environment will be identified. The arrival time and intensity of solar flare initiated blast waves propagating through the interplanetary medium and arriving at the Earth will be predicted. Interplanetary measurements essential for diagnostic research of specific solar-terrestrial events that perturb the aerospace environment will be defined.

2. Solar Physics Research (RO 3.1.2): Research will be done in order to develop an understanding of the physical processes encountered in interactions between magnetic fields and the solar plasma. Convective and oscillatory motions, and the transfer of their energy from the solar interior into and through the solar atmosphere will be studied; the structure of the solar corona and short and long-term variations will be studied. Speckle and active optics reconstruction of solar images compensated for degradation by atmospheric turbulence and techniques to be used in the upcoming Spacelab 2 and solar optical telescope (SOT) Space Shuttle missions will be pursued. Solar-like activity in other stars, with specific emphasis on the relationship and interaction between chromospheric activity, luminosity variations, rotation, and the comparative morphology of solar and stellar surface activity will be investigated.

3. Solar Radio Research (RO 3.1.3): Research will be conducted in order to develop an understanding of solar radio burst and active region radiation to identify prediction signatures of solar geophysical phenomena. We will try to improve our understanding of the process by which protons and electrons are accelerated in solar flares and gain insight into the forces that drive coronal waves, examining both statistically and by individual cases, the relationship between coronal shock waves and geomagnetic storms.

4. Magnetospheric Modeling (RO 3.1.5): Research will investigate the production and transport of magnetospheric plasma populations; specify causes of magnetospheric substorm phenomenology and establish stability criteria for magnetospheric plasmas. Work will be directed toward the development of a complete magnetospheric model in order to predict the expected particle population encountered by future operational systems.

5. Solar/Particle Radiation Effects (RO 3.1.6): The energetic solar flare particle flux to spacecraft at various geographic latitudes and altitudes will be predicted. Algorithms to compute the cosmic ray exposure to spacecraft orbiting at various low altitudes will be developed. Particle spectrometers will be constructed capable of determining the electron and ion population between 20 keV and 300 keV with discrimination according to ion mass.

6. Magnetosphere-Ionosphere Coupling (RO 3.1.7): Studies will be made of the production and maintenance of polar ionosphere. The relative contributions of magnetospheric plasmas and fields to formulation of density irregularities in the high latitude ionosphere will be determined. Observations and analysis will be conducted of the acceleration of cold plasma at high latitudes and transport to magnetospheric altitude. Dynamic models of substorm efffect in midnight sector will be specified and developed.

7. Spacecraft Hazard Predictions and Spacecraft Charge Buildup (RO 3.1.8): Spacecraft charging conditions in high latitude ionosphere will be specified. The generation of plasma waves in the Space Shuttle environment will be investigated. Algorithms will be derived for the determination of space vehicle potential in real time.

8. Active Space Environment Modification (RO 3.1.9): Studies will be made of the generation, transport and measurement of waves during artificial beam injections into space plasmas. Computer models will be developed to simulate and predict wave modes generated during beam emissions.

9. Interplanetary Research (RO 3.1.11): Research will be conducted to determine how solar wind particles couple into the Earth's magnetosphere. Studies will be made of the relationships between solar wind characteristics, interplanetary magnetic field configurations, and the storage and release of energy in the Earth's magnetosphere associated with substorm activity.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Predict the occurrence and intensity of enhanced particle fluxes which affect Air Force systems operating in near-Earth space.

b. Define solar and interplanetary phenomena which can affect the environment in which present and projected USAF systems operate.

c. Predict the effect of plasma irregularities and motions on Air Force systems.

d. Develop new instruments to measure the wake and sheath properties of spacecraft to study communications, detection and tracking.

e. Forecast solar electromagnetic and particle emissions that disrupt high frequency communications, radars and satellite sensors.

f. Improve satellite imaging techniques to determine the purpose and performance of Earth-orbiting satellites.

g. Determine long term solar energy output variations as input to upper atmosphere models and long range weather prediction.

h. Determine the spatial-temporal variation of the solar wind at the Earth which produce disturbances that adversely affect Air Force systems.

i. Improve Air Force space vehicle reliability and survivability.

j. Provide data essential for the design and high performance of communication, guidance and surveillance systems under normal and disturbed conditions.

k. Develop techniques of solar observations to be used on Space Shuttle missions.

l. Derive from direct measurements, the characteristics of space shuttle environmental electromagnetic interference (EMI).

m. Provide algorithms for the real-time prediction of solar particle events which disrupt the performance of AF C^3I systems.

n. Extend the warning time and impact accuracy of solar particle events using characteristics of solar radio emission.

o. Develop algorithms which can be used as input to satellite radiation dosage calculations for the cosmic ray angle of arrival as a function of energy and momentum.

p. Provide forecasts of dangerous radiation hazard for man-in-space.

q. Improve forecasts of communications disruptions in polar regions.

r. Reduce false alarms from early-warning systems.

s. Predict the expected space particle population encountered by future operational systems.

t. Predict ionospheric behavior and its system impact, such as satellite drag, IR emission enhancements and communication/surveillance responses to electron density irregularities.

u. Permit longer space vehicle lifetimes and better operational capabilities in a hostile environment by actively modifying the near-Earth environment to reduce trapped particle fluxes in the radiation belts, alter optical background levels, and enhance trans-ionospheric signal propagation.

SUBAREA 3.1 FY 85 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 3.1 ($K)
2311A1	Space Physics	3337	1100
2311G4	Solar-Terrestrial Coupling	1183	1183
2311G5	Magnetospheric Processes	1342	1342
2311G3	Solar Research	1912	1544.8
	TOTAL		5169.8

AFOSR Focal Point: Lt Col Gerald J. Dittberner
Telephone: (202) 767-4960

TECHNICAL AREA: Geophysics

SUBAREA NUMBER AND TITLE: 3.2 Optical/IR Environment Research

GENERAL OBJECTIVE: This subarea encompasses research on the optical and infrared transmission, absorption, and emission properties of the atmosphere and its constituents. The broad objective is to understand the atmospheric processes which may affect the design or operation of communciation, navigation, surveillance, and weapon systems which utilize optical or infrared signals. The investigations include both the average conditions of the atmosphere and the variations that could arise from natural distrubances or from military operations. Of particular interest are the distributions, interactions, and energetics of atmospheric molecules observed in the laboratory and in the free atmosphere, the theoretical description and modeling of radiative processes, and the development of remote sensing techniques.

RESEARCH EFFORTS:

1. Atmospheric Transmission/Absorption (RO 3.2.1): Several spectroscopic techniques are to be applied to the study of photodissociation processes and to the improved understanding and modeling of absorption/emission line widths and shapes. Photofragment spectroscopy and supersonic free jet techniques will be used to study photodissociation of large van der Waals molecule and other atmospheric constituents. Spectroscopic measurement of absorption in the troughs between H_2O and CO_2 lines will aid development of the theory of line shapes and contribute significantly to the understanding of the radiation budget. Molecular emissions from trace gases in the stratosphere are to be studied by means of balloon-borne spectroscopic measurements. These are expected to aid the understanding of stratospheric chemistry and the development of transmission/emission codes.

2. Auroral and Nuclear Backgrounds (RO 3.2.2): A laboratory cryogenic chamber is to be used to study infrared emissions from atmospheric constituents excited by electron beams or by chemiluminescence techniques. Laser excitation of specific states of CO_2, N_2O, O_2, and N_2 will be used to study energy transfer which gives rise to infrared radiation in the upper atmosphere. The production and loss processes of infrared active species will be observed during an auroral experiment. Measurements from rockets and from satellites, including the space shuttle, will be used in the development of a theoretical description of the spatial and temporal variations of infrared emissions in the auroral zone. A Nd:YAG laser system will be used to produce an electrodeless breakdown in air, producing a local perturbation of high energy density simulating a nuclear detonation in the upper atmosphere. The resulting radiation will be studied to determine its kinetic, spectral, and intensity characteristics.

3. Natural Airglow (RO 3.2.3): A cryogenic chemiluminescent reaction chamber will be used to study the processes controlling infrared emissions from carbon

monoxide, atomic oxygen, nitrogen, and high metastable states of molecules. Kinetic rates governing these processes are to be determined. Laser techniques will be applied to determine the effect of vibrational energy content in N_2 and O_2 on upper atmospheric luminesrence. Laser excitation and fluorescence techniques will also be used to investigate ozone production processes, measure the transition probabilities of excited vibrational levels and investigate intramode transfer kinetics. Altitude-dependent models of atmospheric radiance will be developed to describe the quiescent atmospheric baseline for infrared radiance. The kinetics and dynamics processes of small molecules will be studied.

4. Celestial Backgrounds (RO 3.2.4): Photometric standards will be established for stars of magnitude 12 to 17 over a wide range of color index. Celestial x-ray sources discovered by the Einstein Observatory satellite will be observed at radio and optical wavelengths. Information will be acquired on the optical and physical properties of interplanetary dust, including its distribution, origin, dynamics, and contribution to the infrared astronomical background. Celestial sources of infrared radiation will be observed and classified. All these measurements will contribute to an understanding of the celestial radiation background and to the development of target discrimination techniques.

5. Optical Aerosol Modeling (RO 3.2.9): Models of optical properties of aerosols are to be developed in order to calculate such parameters as beam attenuation, angular scattering intensities, polarization, path radiance, and contrast transmission. This development will be aided by a variety of experimental efforts. Spectroscopic measurements of optical and infrared constants of aerosol samples will be refined and these measurements will be used to relate aerosol refractive index, size distribution, and concentration to meteorological conditions. Experimental and theoretical studies will be conducted to determine the relationship to anisotropic bulk optical constants of aerosol substances to the optical properties of aerosol particles consisting of pure and mixed substances. A tethered balloon will be used to obtain vertical profiles of aerosol size and concentration in the lower atmosphere for comparison with simultaneous lidar and slant-path transmittance data.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Develop the technology for space based missile surveillance systems.

b. Develop techniques for the forecasting of atmospheric transmission in support of electro-optical weapon systems.

c. Develop computer models of atmospheric transmission, absorption, and emission to support the design of electro-optical sensors.

d. Determine the practicability of using various laser wavelengths for long path ranging, for communications, or for weapon systems.

e. Develop discrimination schemes to extract target signatures from unwanted clutter in space based bomber detection systems.

f. Determine the energy cascade and emission characteristics of a nuclear environment which would affect communications and mask target signatures.

SUBAREA 3.2 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 3.2 ($K)
2303B1	Molecular Dynamics	3757	1189
2310A1	Meteorology	1270	110
2310G1	Molecular and Aerosol Properties of the Atmosphere	1300	1300
2310G4	Infrared Atmospheric Processes	2540	2540
2311A1	Space Physics	3337	2237
	TOTAL		7376

AFOSR Focal Point: Lt Col Gerald J. Dittberner
Telephone: (202) 767-4960

TECHNICAL AREA: Geophysics

SUBAREA NUMBER AND TITLE: 3.3 Ionospheric Research

GENERAL OBJECTIVE: Research within this subarea seeks to define the physical and chemical properties of the earth's upper atmosphere and to determine the effects of such properties on Air Force systems operating therein. Atmospheric regions of interest are the stratosphere, mesosphere, thermosphere, and the D, E, and F regions of the ionosphere. Particular research topics include understanding the physical processes in the ionosphere, effects on transionosphere communications, ionospheric disturbances and modification, absorption chemistry, and ultraviolet processes in the ionosphere.

RESEARCH EFFORTS:

1. Ionospheric Physics (RO 3.3.1): A variety of theoretical and experimental programs are being pursued toward the general goals of understanding the physical and chemical structure of the ionosphere in both quiescent and disturbed states. Coordinated observations of the ionosphere by radars at three locations are being used, together with numerical simulations, to understand spatial and temporal variations in electron density and other parameters. Models will be developed to describe observations of the D-region with rocket-borne and balloon-borne instruments and to describe the transport of meteoric metals in the ionosphere. A theory of wave-particle interactions will be developed and applied to the study of plasma turbulence. Techniques for observing the ionosphere from satellites and from the ground will be refined on the basis of new knowledge of ionospheric processes. Energy deposition at high latitude and the latitudinal propagation of disturbance will be studied by means of models and observations from satellites and ground-based radars.

2. Ionospheric Disturbance and Modification (RO 3.3.2): A multi-function mass spectrometer is to be flown on the Space Shuttle to measure the outgassing neutral environment, the ionized species, and the spacecraft electric potential environment. Mass spectrometers and other instruments will be flown on balloons and rockets to measure ionospheric species and determine the physical-chemical processes that are of importance to ELF/VLF/HF communications. Chemical release experiments will be conducted to provide understanding of ionospheric irregularities, neutral motions, and electronic fields.

3. Atmospheric Chemistry (RO 3.3.3): Experimental programs are being conducted to investigate ion-ion and ion-neutral reactions that are of importance to the chemistry of the upper atmosphere. Reactions of interest include reactions of negative ions with water and the oxides of carbon, nitrogen, and sulfur; the recombination of electrons and positive ions; and the attachment of electrons to neutral molecules. Radiative and collisional quenching reactions of species important as sources of infrared or optical emission will also be studied. Techniques to be used in these studies include laser-induced multiphoton dissociation, ion cyclotron resonance spectroscopy, and selected ion flow tube (SIFT), and laser fluorescence methods.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Prepare information for inputs to future stratospheric pollution standards so that Air Force operations will not be unduly restricted.

b. Understand composition and physical processes of the upper atmosphere to minimize environmental effects on performance of Air Force communication, surveillance, and weapon systems.

c. Predict atmospheric changes affecting vehicle trajectories to assist in the tracking of space vehicles.

d. Provide the technology to develop methods to reduce radar cross sections of reentering ballistic missiles.

e. Improve the capability to detect nuclear detonations.

f. Provide the basis to develop improved models of nuclear weapons effects on communications and radar systems.

g. Develop the ability to disrupt enemy systems which depend on the ionosphere for their operation.

h. Derive auroral energy deposition in real time to enable communication link outages to be forecast and alternate routes provided.

i. Derive from direct measurements, the characteristics of space shuttle environmental electromagnetic interference (EMI).

SUBAREA 3.3 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 3.3 ($K)
2303B1	Chemistry of the Ionosphere	3757	724
2303G1	Upper Atmosphere Chemistry	535	535
2310A2	Upper Atmosphere Structure and Dynamics	893	893
2310G3	Upper Atmosphere Composition	2450	2450
2310G6	Local Ionospheric Processes	642	642
2310G9	Global Ionospheric Dynamics	650	650
	TOTAL		5894

AFOSR Focal Point: Dr. Henry Radoski
Telephone: (202) 767-4906

TECHNICAL AREA: Geophysics

SUBAREA NUMBER AND TITLE: 3.4 Earth Science Research

GENERAL OBJECTIVE: This research relates to and draws upon the efforts of a wide range of geodetic and geophysical techniques and instrumentation necessary for the support of Air Force weapons systems, reconnaissance, target acquisition, and weapon delivery. This objective requires research in geodesy: position determination, parameters relative to the shape, size, and dynamics of the Earth; gravity: measurement and modeling of the geo-potential; and geophysics: environmental noise and motion in the crust of the Earth.

RESEARCH EFFORTS:

1. Geodetic Research (RO 3.4.1): Research will be directed toward the development of instrumental and analytical techniques to allow highly accurate measurements of the Earth's size, shape and dynamic motions in order to improve USAF capability for precise positioning of weapons systems.

2. Gravity Research (RO 3.4.2): Analysis of satellite altimetry data and the development of sensitive accelerometers will enhance the capability to model and predict the Earth's gravitational field, particularly in ocean areas, at accuracy levels required by USAF strategic weapons systems.

3. Earth Motion (RO 3.4.3): Research will be directed to the development of theory, instrumentation and techniques to determine the causes and predict the amplitude and duration of Earth motions over a wide range of frequencies at specific locations. The parameters and frequencies invovled for siting, testing, and operating Air Force systems in the terrestrial environment will be determined.

4. Seismological and Geological Studies (RO 3.4.4): Earthquake source mechanisms and seismic and acoustic wave propagation will be studied. The geological and geophysical properties of the Earth's crust will be characterized.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Improve azimuth reference systems and launch and target position determinations through geodetic studies.

b. Provide the geodetic information required to reduce the CEP of advanced ballistic missile systems.

c. Improve targeting of strategic weapon systems and weapon delivery through gravity investigation.

d. Develop techniques required to develop precise inertial navigation systems.

e. Predict effects of earthquakes, explosions, tides and tilt on stability and vulnerability of missile systems.

f. Provide the technology to improve the stability of missile guidance systems.

g. Predict effects of environmental noise on Air Force systems.

SUBAREA 3.4 FY 85 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 3.4 ($K)
2309A2	Earth Physics	891	891
2309G1	Geodesy and Gravity	1050	1050
2309G2	Crustal Motion Studies	781	781
	TOTAL		2722

AFOSR Focal Point: Lt Col Gerald J. Dittberner
Telephone: (202) 767-4960

TECHNICAL AREA: Geophysics

SUBAREA NUMBER AND TITLE: 3.5 Atmospheric and Meteorological Research

GENERAL OBJECTIVE: The research included in this subarea is aimed at specifying and predicting the physical and dynamical processes and conditions in the lower atmosphere and the neutral upper atmosphere. These processes or conditions may impede or facilitate the conduct of Air Force operations, impacting the design and operation of virtually all communication, surveillance, reconnaisance, and weapon systems. For example, knowledge of the spatial and temporal distribution of rain and cloud drop sizes is critical to the design of certain radars, airfoils, reentry vehicles, and communication systems; accurate forecasting of winds can enhance the performance of aircraft operations. Topics of investigation include atmospheric dynamics at global and regional scales, microphysics and dynamics of clouds and cloud systems, atmospheric electrical phenomena, and the use of satellites in global remote atmospheric sensing. (Excluded from this subarea are the scattering and absorption of optical and infrared radiation by aerosols and ice crystals, which are addressed in Subarea 3.2.)

RESEARCH EFFORTS:

1. Large Scale Dynamics/Prediction (RO 3.5.1): High-resolution, full vector wind data from VHF radars will be used to study average transport and diffusivity in the lower and middle atmosphere and to study dynamic phenomena such as wave/wave interactions and tidal forcing. New radiative transfer parameterizations will be incorporated into high-resolution global models and impacts will be evaluated with and without the new boundary-layer parameterization. New convective adjustments will be made in the high-resolution models, and improved representation of moisture exchanges involving different vegetation covers over the land surface will be sought. Improved treatment of moisture, previously developed, will be tested on independent data sets and with models having the new parameterization schemes. A method for incorporating satellite data into the routine data assimilation procedure will be developed.

2. Intermediate-to-Small Scale Dynamics/Prediction (RO 3.5.2): The internal structure, precipitation processes, and dynamics of medium scale storm systems will be investigated through field programs and theoretical modeling. The role of low level motion and terrain in the development of mesoscale systems will be studied. The capability of numerical models to predict mesoscale development, especially from synoptic scale data bases, will be evaluated and will be used to evaluate techniques for incorporating radiometric temperature profiles and VHF radar wind profiles into the forecasting process. A relocatable regional model imbedded in a global model for simulation and prediction of a limited region will be designed and coded. Methods of defining boundary conditions for the relocatable regional model, using outputs from a global model, will be investigated.

3. Cloud Microphysics (RO 3.5.3): Investigative studies of droplet nucleation, high humidity aerosol behavior, and aerosol/droplet size spectra development will be initiated using the new cloud simulation chamber at the University of Missouri-Rolla.

4. Physics and Dynamics of Precipitation Systems (RO 3.5.4): Research on precipitation microphysics and dynamics will be conducted using polarization diversity radar, Doppler wind profilers, and a temperature and humidity profiler to study precipitation development, storm organization, and turbulence. The evolution of cloud dynamics and bulk properties will be studied with one, two, and three dimensional mesoscale models incorporating potentially useful parameterizations of liquid water, size distributions, and other microphysics.

5. Atmospheric Electricity (RO 3.5.5): Theoretical and laboratory studies will be conducted to investigate the distribution of electric charge in clouds and the importance of the lightning step-leader to subsequent interaction of lightning discharges with aircraft surfaces.

6. Boundary Layer Dynamics (RO 3.5.6): A model to study the turbulent boundary layer will be developed, which includes water vapor, irregular terrain, surface roughness, and inhomogeneous surface fluxes. An atmospheric dispersion model that includes thermodynamics, chemical reactions, and atmospheric structure properties for heavy gas sensitivity will be investigated.

7. Climatological Modeling (RO 3.5.7): Theorectical and modeling studies will be conducted into physical mechanisms underlying climate variations on monthly, and yearly time scales, and on regional and global space scales.

8. Satellite Meteorology (RO 3.5.8): Theoretical and experimental studies will be conducted to use multi-spectral infrared sounding observations to depict atmospheric structure (temperature, moisture, clouds, and surface parameters). Techniques for assimilating satellite data for Numerical Weather Prediction will be tested. Sources of error associated with the differential inversion technique to retrieve temperature, will be quantified. Satellite techniques for snow and cloud monitoring on the marginal cryosphere will be developed. Data sets from satellite and surface stations will be analyzed to establish the detailed characteristics of clouds and of snow-ice fields.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Develop increasingly accurate numerical weather prediction models which can extend the forecast period in support of tactical and strategic systems.

b. Develop weather prediction models incorporating satellite-derived data to support worldwide Air Force operations.

c. Develop the capability to obtain meteorological data on a global basis.

d. Define the hydrometeor (cloud and precipitation particle) environment for optical and infrared transmission.

e. Define the basic state and diffusivity of various atmospheric layers as inputs to models describing the impact of Air Force systems upon their environment.

f. Model natural lightning effects so that realistic protection and design criteria may be developed.

SUBAREA 3.5 FY 85 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 3.5 ($)
2310A1	Meteorology	1270	1160
2310G7	Atmospheric Prediction	1405	1405
2310G8	Atmospheric Specification	815	815
	TOTAL		3380

AFOSR MANAGER: Dr Michael J. Salkind
Telephone: (202) 767-4987

TECHNICAL AREA 4: Aerospace Vehicles

INTRODUCTION

Air Force mission requirements for aerospace vehicles span the range from very low speed aircraft (V/STOL) through subsonic transports and fighters, subsonic/supersonic bombers and fighters, to hypersonic vehicles, and spacecraft. The supporting technologies for developing these vehicles include structures, aerodynamics, and controls. As we look toward the future, we see more flexible and maneuverable aircraft that can be actively controlled, will be more fuel efficient and reliable, and can operate from shorter runways. We see larger, more flexible spacecraft that will require accurate figure control and pointing accuracy. These future needs highlight shortcomings in our basic understanding and design tools and identify the focal points for our research.

This technical area plan is organized into three subareas and one initiative. The subareas are Structures, Fluid Mechanics, and Controls, and the initiative, which begins in FY 86, is Maneuverability. Contributing substantially to these subareas are the FY 82 initiatives in Fuel Efficient Aircraft and Low Speed Take-Off and Landing, and the FY 83 initiative in Spacecraft Materials and Structures. These initiatives are interdisciplinary and major elements of each have been incorporated into the three subareas of this technical area.

The Structures subarea emphasizes dynamics, control interactions, nonlinear analysis, aeroelasticity, and durability. The FY 83 Initiative in Spacecraft Materials and Structures contributes substantially to structural dynamics and control interaction. Durability research is shifting to damage tolerance. In Fluid Mechanics, major emphases are in turbulence, computational fluid dynamics, and unsteady aerodynamics. We plan more research into the reduction of drag by passively and actively controlling structure in turbulent flows, solution-adaptive computational grid generation, and unsteady separated flows. The Controls subarea is shifting from traditional math approaches, which have been developed sufficiently to support the increased development activity at the Wright Aeronautical Laboratories (AFWAL), toward distributed (decentralized) controls and approximation of higher order systems.

The FY 86 Initiative in Maneuverability will exploit controlled unsteady separated flows for enhanced force and moment generation in the post-stall environment. The research will focus on separated flow driven by time dependent boundary conditions and on coupled, nonlinear fluid-structures interactions. The foundations will be provided for advanced aerodynamic concepts for future generations of highly maneuverable aerospace vehicles.

FY 86 PLANNED FUNDING:

MAJOR THRUST INITIATIVE:	FUNDING ($K)
Maneuverability	1500
TOTAL	1500

SUBAREA NUMBER	TITLE	FUNDS SPTG SUBAREA ($K)
4.1	Structural Mechanics	7929
4.2	Fluid Mechanics	8874
4.3	Flight Control	1325
	TOTAL	18128
	TECHNICAL AREA TOTAL	19628

AFOSR Focal Point: Dr J M McMichael
Telephone: (202) 767-4935

TECHNICAL AREA: Aerospace Vehicles

MAJOR THRUST INITIATIVE: Maneuverability

GENERAL OBJECTIVE: Advanced aerodynamic concepts based on enhanced lift generation by controlled unsteady flows will be needed for future generations of highly maneuverable aerospace vehicles. The objective of this initiative is to provide the scientific and conceptual foundations for a new enabling technology which will exploit controlled unsteady separated flows for enhanced maneuverability in the post-stall environment. This will require fundamental research on the behavior of unsteady separated flows driven by time dependent boundary conditions, investigation of highly coupled, nonlinear fluid-structure interactions, and development of advanced actuator and flow control concepts.

RESEARCH EFFORTS:

1. Unsteady Separated Flows: Fundamental unsteady separated flow characteristics for generic two and three-dimensional aerodynamic lifting surfaces undergoing time-dependent motions will be investigated experimentally using flow visualization and measurements of velocity and pressure fields as well as of overall time-dependent forces and moments. Criteria for the onset of three-dimensional unsteady flow separation will be developed. Interactions between natural organized structure in unsteady separated shear layers and large scale organized lifting vortices will be studied experimentally. Three-dimensional instabilities of organized lifting vortices and the influence of streamwise (corewise) vortex stretching on the stability and controllability of organized separated flows will also be examined. Comparative experimental studies at various Mach and Reynolds numbers will be conducted to determine the dynamical importance of compressibility and viscosity in organized unsteady separated flows. The effects of motion history on unsteady flow behavior will be studied experimentally for selected simple three-dimensional geometries. Passive surface modifications, flexible bodies, acoustic forcing, time-dependent localized jets, and various mechanical actuators will be explored to develop techniques for controlling and enhancing desired unsteady flow characteristics.

2. Fluid-Structure Interactions: Methodologies for accurate and reliable analytical and computational models capable of simulating complex nonlinear, time-dependent, coupled fluid-structure interactions will be developed by coupling nonlinear large amplitude structural deformation equations with those describing unsteady aerodynamic loading. Analytical and computational models based on these coupled equations will be solved simultaneously to provide information on the coupled behavior of flexible structures and controlled unsteady flow fields. The potential for aeroelastic tailoring concepts for managing unsteady separated flows will be explored. New developments in the theory of distributed parameter control will be integrated with advances in predictive capability for fluid-structure interactions to provide the theoretical foundation for new concepts in aero-servoelasticity.

FY 86 PLANNED FUNDING: $1500K

AFOSR Focal Point: Dr Anthony K. Amos
Telephone: (202) 767-4937

TECHNICAL AREA: Aerospace Vehicles

SUBAREA NUMBER AND TITLE: 4.1 Structural Mechanics

GENERAL OBJECTIVE: The Structural Mechanics Subarea is concerned with the structural response of aerospace vehicles (aircraft, missile and spacecraft) and subsystems to their operational and service environments. Response issues of interest include stresses and deformations (static and dynamic), buckling, flutter, vibrations, fatigue and fracture. Major environmental factors of concern are external loads due to aerodynamics, impact and contact with or without rolling, internal loads due to interactions with propulsion and controls subsystems as well as with thermal sources, and material property variation with environmental exposure and normal operational damage processes. Research in this subarea provides basic understanding and analytical/experimental methods for the prediction of phenomena associated with loads, aeroelasticity, strength, stability, fatigue, fracture, shock and vibration. It additionally provides techniques for the design and synthesis of structural components to enhance total vehicle system performance, reliability and maintainability.

RESEARCH EFFORTS

1. Fracture Mechanics and Fatigue (RO 4.1.1) - Establish fundamental principles governing the initiation and growth of cracks in structural components and develop analytical methods for modeling fracture processes, with due consideration of both deterministic and stochastic factors. Continue development of scientific basis for damage accumulation processes under acoustic loading.

2. Composite Damage Processes (RO 4.1.1) - Develop a general damage growth prediction methodology for laminates with strain concentrations or localized damage states. Continue development of unified strength/fatigue theory for resin-matrix components.

3. Dynamics and Control (RO 4.1.2) - Develop methods for the simulation of the transient dynamic behavior of flexible structures including interactions with electronic control subsystems. Develop concepts and analytical models for active and passive control of orbital dynamics (including deployment) of flexible spacecraft systems. Formulate procedures for simultaneous synthesis and optimization of spacecraft structure and controls.

4. Aeroelasticity (RO 4.1.3) - Improve potential theory modeling of unsteady flows of aircraft lifting surfaces and external stores to better capture shock and separated flow aeroelastic effects. Identify composite tailoring effects on stability characteristics of aircraft. Develop robust sclution algorithms for coupled structure and fluid nonlinear equations. Develop time-domain aeroservoelastic modeling capability.

5. Analytical Methods (RO 4.1.5) - Develop constitutive models and analysis methods for structures comprising inelastic, temperature and rate sensitive, monolithic and multiphase materials. Develop improved nonlinear solution algorithms and account for structural stochastics. Develop methods for thermomechanical interaction analyses, accounting for varying degrees of internal damage. Characterize impact resistance of composite structures at high strain rates.

6. Multidisciplinary Design (RO 4.1.6) - Continue research in multivariable distribution theory and construct multistate reliability models. Develop methods for nonparametric statistical analysis of reliability models and Bayesian inference capabilities.

APPLICATIONS TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Establishment of stiffness requirements for vehicle and weapon systems structures to insure system performance, stability and durability.

b. Damping and structural configuration concepts to minimize vibrations and noise in man-rated vehicle systems.

c. Prediction of structural response to system operational environments and their consequences in terms of strength, stability and durability.

d. Active control and aeroelastic tailoring concepts for stability augmentation and load alleviation in aeronautical systems, and for shape control and rapid decay of vibrational disturbances in precision space structures.

e. Optimal synthesis of structural configurations for aerospace vehicles and weapons systems to strength, stiffness, fatigue, durability and cost criteria.

f. Innovative concepts and a confidence base for the use of advanced composite materials in vehicle structures.

g. Damage tolerant design concepts for insuring integrity and durability of structural subsystems.

h. Accelerated life testing and nondestructive evaluation methods for advanced structural materials.

SUBAREA 4.1 FY86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	SPTG SUBAREA 4.1 ($K)
2302B1	Mechanics of Structures	2600	2200
2302B2	Structural Durability	3443	2804
2302F2	Validation of Large Space Structures Modeling & Control	35	35
2302N1	Behavior of Metallic and Composite Components of Airframe Structures	730	730
2302N5	Structural Dynamics & Controls	480	480
2304A1	Mathematics of Dynamics & Control	2250	75
2304A3	Mathematics of Computation	3000	175
2304A5	Statistics and Probability	3100	800
2304A6	Mathematics of Signal Processing and Communications	900	375
2304N1	Computational Aspects of Fluid and Structural Mechanics	380	255
	TOTAL:		7929

AFOSR Focal Point: Dr J D Wilson
Telephone: (202) 767-4935

TECHNICAL AREA: Aerospace Vehicles

SUBAREA NUMBER AND TITLE: 4.2 Fluid Mechanics

GENERAL OBJECTIVE: The Fluid Mechanics subarea encompasses research to illuminate the behavior and controlling mechanisms of complex flow fields associated with aerospace vehicles having configurations and operating in flight regimes of importance to the Air Force. The overall objective is to provide the foundation of basic knowledge essential for the successful development of advanced vehicles and systems capable of satisfying future Air Force mission requirements. In order to achieve this goal, research is conducted to provide both physical understanding of key flow phenomena and modeling capability based on that understanding, to devise advanced theoretical analysis techniques, and to originate new concepts which have promise for expanding current aerodynamic performance boundaries. The range of topics includes the determination of the role of turbulence structure in boundary layers and free shear layers; improved modeling for strongly interacting viscous flows; improvement in the efficiency, stability and accuracy of numerical methods for three-dimensional viscous and nonlinear inviscid flows; determination of the qualitative and quantitative features of separated and attached unsteady flows; improved prediction capability and innovative thrust augmentation concepts for powered lift aerodynamics; and determination of the factors governing the stability of high speed boundary layers, as well as the role of surface roughness in heat transfer augmentation (Subareas with related ROs: 5.2, 5.3, 6.2, and 6.3).

RESEARCH EFFORTS:

1. Inviscid Aerodynamics (RO 4.2.1): New methods will be sought for numerical solution of the Euler equations for transonic and supersonic flows. Emphasis will be placed on methods suitable for complex three-dimensional configurations, including exploration of the physical significance of inviscid modeling of separation. Multilevel grid techniques will be considered for solving the global flow field with solution dependent features for maintaining consistency between subdivisions.

2. Boundary Layers in High Speed Flows (RO 4.2.2): Better understanding of boundary layer stability phenomena in hypersonic flow will be pursued. Experimental studies will be performed for a 7 degree cone at Mach 8 to determine the effects of small nosetip bluntness and unit Reynolds number on boundary layer stability. In other work, the effects of surface roughness on heat transfer and surface shear will be studied for Mach 3 flow past a flat plate. By means of flow field and surface measurements, the effects of roughness height, roughness distribution and adverse pressure gradient will be quantified. In addition, the combined effects of surface mass addition and surface roughness will be investigated to determine if the combined effects can be estimated by superposition or if the effect of mass addition alters the mechanisms which cause roughness heating.

3. Powered Lift Aerodynamics (RO 4.2.3): Better prediction procedures for the induced effects of energetic, turbulent jets on VSTOL flight vehicles are

required. In order to overcome this deficiency, phenomena associated with multiple jet/jet and jet/surface collisions and jets in cross flow will be explored. Experimental and numerical investigations will focus on the turbulence features of upwash fans created by colliding wall jets and on multiple jets in cross flow in close proximity to a ground plane. The emphasis of the research will be on turbulence structure in high strain regions and on the time-dependent feature of the overall flow fields.

4. Unsteady Flows (RO 4.2.4): The focus of this unsteady flow research is on developing understanding of the dynamics of attached and separating unsteady flows resulting from imposed time-dependent boundary or initial conditions. The goal is to identify, characterize and predict unsteady flow phenomena which may be exploited for aerodynamic load enhancement. The research will include fundamental studies on the nature of unsteady boundary layers near the location of an evolving, time-dependent separation and on the influence of motion time history on evolution and control of separation. In addition, mechanisms for unsteady lift generation on wings by means of energetic separation will be examined experimentally for a wide range of motion and flow conditions. Of particular interest are the effects of motion history, three-dimensionality, compressibility and Reynolds number. Analytical and numerical methods will be sought which can capture the key features of unsteady, separated flow and thus be used with confidence for flow prediction.

5. Structure of Turbulence in Shear Layers (RO 4.2.5): The goal of this research on turbulent flows is to develop understanding of the fundamental mechanisms governing the onset, production and sustenance of turbulence through the concept of coherent, Lagrangian structures in surface bounded and free shear layers. Coupled with this focus on understanding of mechanism is the goal of controlling these flows by passive and/or active manipulation of the turbulence structure. The process of transition from laminar to turbulent wall-bounded flow will be studied using several approaches, including numerical solution of the full time-dependent Navier-Stokes equations and experimental modeling by means of generating isolated turbulent spots in laminar boundary layers and studying the attendant instability mechanisms. In addition, new theoretical tools based on concepts from the mathematical theory of chaos will be explored to describe the onset and evolution of turbulence in convectively unstable flows. Experimental studies will continue on examining the mechanisms responsible for production and regeneration of turbulence in fully developed turbulent boundary layers. Increasing emphasis will be placed on structural features of boundary layers subject to compressibility, pressure gradient, and flow curvature effects. Turbulent flow control studies will encompass work related to reduction of friction drag for boundary layer flow and mixing control for jet flows. Passive devices will be explored in boundary layer flows for altering the turbulence production mechanisms; active and interactive control of transitional turbulent spots will be investigated experimentally using surface mounted heated strips in a laminar boundary layer in water. Techniques to alter the turbulent structure of subsonic jet flows through passive geometry modifications, active forcing and interactive (feedback) control will be explored experimentally.

6. Complex Viscous and Separated Flows (RO 4.2.6): One focus of research in this area is on determining the governing physical mechanisms and improving the theoretical modeling capability for strong shock wave-turbulent boundary layer interactions. Experimental studies to determine the physical structure and scaling of such interactions with Reynolds number, Mach number and

incoming boundary layer characteristics will be pursued along with full numerical simulations based on Reynolds-averaged Navier-Stokes equations and theoretical modeling based on non-asymptotic triple deck procedures. Both supersonic and hypersonic free stream Mach number cases will be considered. Other work will address the flow characteristics associated with supersonic flow past sharp-edged delta wings. The condition of subsonic leading edges will be investigated in a joint experimental/computational effort to understand the secondary vortex pattern which occurs. Finally, several approaches for numerically modeling viscous-inviscid interactions will be pursued, including those based on inviscid flow/inverse boundary layer coupling and on consistent, reduced formulations of the Navier-Stokes equations.

7. Numerical Methods in Fluid Dynamics (RO 4.2.7): The overall goal of research in this area is to devise computational techniques for solving the partial differential equations of fluid dynamics numerically in an efficient, stable, and accurate fashion. Of particular interest are methods suitable for steady and unsteady flow past complicated three-dimensional shapes in compressible flow. To this end, methods will be pursued which are suitable for use on the most powerful vector computers; the possibility of exploiting increased parallelism in future computers will be assessed. Better procedures of error estimates associated with the major solution techniques will be pursued. For example, a multigrid process will be used with a standard Navier-Stokes code to apply error norms to quide grid adjustments and set residual tolerances. One of the major numerical problems in fluid mechanics being addressed in this research area is the need for automatic coordinate generation capable of handling complex geometries. Some novel techniques like the multisurface coordinate transformation scheme, variants of the body-fitted coordinate scheme, and other algebraic and geometric ideas will be pursued. Additional problems to be studied include the correct formulation of well-posed and stable subsonic boundary conditions and procedures for solution-driven grid adaption. Finally, preliminary efforts will be directed toward coupling the fluid dynamics equations with the equations for elastic structures and for flight mechanics. Model problems will be formulated to explore fundamental issues assocated with this coupling.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Provide more reliable, efficient, and accurate flow field modeling capability, including computational, analytical, and experimental testing methods. Advanced modeling capability is critical to the development of future generations of high performance flight vehicles.

b. Expand the flight maneuver envelope by advancing our understanding of steady and time-dependent separated flows.

c. Improve the energy efficiency of flight vehicles by studying ways to reduce turbulent skin friction drag and form drag.

d. Provide increased understanding of the transition to turbulence phenomena which will lead to increased accuracy, improved lift to drag characteristics, and more confident heat transfer predictions for ballistic missiles.

e. Enhance the viability of thrust augmented lift aircraft by advancing understanding of turbulent jet interactions and jet-induced effects in complex three-dimensional flow fields.

SUBAREA 4.2 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 4.2 ($K)
2304A3	Mathematics of Computation	3000	400
2304N1	Computational Aspects of Fluid and Structural Mechanics	380	125
2307A1	External Aerodynamics	3650	3650
2307A2	Structure of Turbulent and Unsteady Flows	2800	2800
2307F1	Aerothermodynamics of Interactive Phenomena	189	189
2307N4	Experimental Aeromechanics	780	780
2307N6	Computational Aerodynamics	930	930
	TOTAL		8874

AFOSR Focal Point: Dr Marc Q. Jacobs
Telephone (202) 767-4940

TECHNICAL AREA: Aerospace Vehicles

SUBAREA NUMBER AND TITLE: 4.3 Flight Control

GENERAL OBJECTIVE: The flight control research subarea concerns the development of methodology and systems required to stabilize and control the motion of manned and unmanned aerospace and space vehicles in all aspects of the conduct of their missions. The required research includes efforts in mathematics, mechanics, and aerodynamics and involves the development of technology for vehicle design and specified stability and control characteristics; for onboard flight control computation, mechanization, and display; and for defining improved aircraft handling qualities under pilot capability constraints.

RESEARCH EFFORTS:

1. Integrated Design (RO 4.3.5.): Increase understanding of integrated configurations of airframe components and their effect on vehicle dynamics, and of the relationships between subsystems and components. Develop nonparametric methods of estimating stimulus-response curves and nonparametric regression techniques for survivability models to determine sensitivity of system survival to system variables. Develop improved modeling capabilities for rough surfaces. Conduct research in applied probability and statistics for practical systems design, analysis and synthesis. Continue development of non-Gaussian and nonparametric multivariate methods to permit the use of wider and more practical classes for the modeling and evaluation of effects and interactions in various configurations. Develop nonparametric methods of estimating stimulus-response curves with applications to control and guidance of vehicles. Improve regression methods to be used in the case of multicollinearity among the regressor variables. Develop time series analysis, particularly multivariate time series, to study systems operating under feedback control and to analyze and evaluate time-varying stochastic systems. Extend modeling of random fields, particularly the non-Gaussian case. Advance the methodology for the design and synthesis of flight vehicles, using existing or proposed subsystems and components to meet overall system configuration and performance specification, and for the analysis and testing of the resulting flight vehicle design. The factors treated include optimal integration of subsystems, studies and analysis of advanced vehicle concepts, man-machine interaction, and the effects of new configurations on thrust and stability. Research will continue in the area of functional analysis methods in systems theory applied to nonlinear and time-varying systems. Techniques will be investigated that promise to aid the solution of the problems associated with very large systems. Further research will be performed in the area of systems identification for the construction of relatively simple models for complex systems, with applications to the design of advanced fighters with increased capability for on-line control. Additional effort will be expended in the area of optimal engineering design, which is aimed at the reduction of costs while keeping performance figures high. Develop effective computational schemes for solving problems in control theory related to flight control. Develop new identification concepts applicable to

nonlinear systems; obtain systems models which closely correspond to the actual systems providing more reliable digital control designs; produce algorithms for use in real time identification, for adaptive control applications. Integrate emerging transonic unsteady aerodynamic methods with structural equations and active control systems to investigate aeroelastic response and flutter suppression for transonic flight. Stochastic system parameter estimation techniques will be sought including the identification of systems of unknonwn structures, both linear and nonlinear. Algorithms efficient enough for on-line use in identification will be coupled with control algorithms to achieve full-state adaptive control. This research concentrates on the analytical dynamics and control of aircraft; it investigates assumptions employed by flight conteol researchers when developing design methodology. Specifically, the research concentrates upon upgrading existing stability and control mathematical models via Lagrange concepts, validating the mathematical models with experimental test data, and the developing flight control analysis and synthesis methods using the more accurate and complete mathematical models. Primary short term research is concerned with estimating unsteady aerodynamic parameters for flight test data via time domain methods such as maximumm likelihood methods and frequency domain methods.

2. Flight Control Performance Criteria (RO 4.3.8.): Develop efficient data collection methods for evaluation of systems performance and selection of the most significant factors contributing to systems response. Study the effect of dramatically reduced sampling rates on flight control system performance. Continue research in optimal design of experiments and robust estimation procedures to provide efficient data collection methods for evaluation of systems performance. Develop exact theory for small samples to analyze data from designs with a low sampling rate. Study multiple-decision theory and its application to the selection of the best subset of a large number of predictor or control variables. Develop digital control systems through the use of multivariable systems. Direct synthesis and analysis of control system. The problems of digital system theory have far ranging applications in modern Air Force systems. For example, the study of vector delay inverses will aid in the determination of minimal time guidance law recovery in a deterministic pursuit/evasion air-to-air encounter, and minimal time ground-based targeting from tracking data. The study of pseudoinverse systems can be applied to aircraft flight test data processing to recover unknown wind gust time histories in the presence of correlated, but otherwise unknown measurement errors. The study of inverses, observers, and feedback control with respect to the above baseline will help in digital flight control systems design for wind gust load alleviation, lateral-longitudinal dynamics, in the presence of unknown wind gust histories.

3. Flight Dynamics Systems (RO 4.3.9.): Define the conditions for applying H-infinity optimization to control synthesis for high-order dynamic systems. Investigate solution techniques for the nonlinear, possibly non-convex H-infinity optimal control solution for a realistic problem such as a flexible aircraft. Investigate practial reduction techniques to define an implementable approximation to the typically high-order compensator that results from H-infinity optimization of unstable or nonminimum phase plants. Research is needed in multi-input multi-output feedback control systems, for which classical methods are inadequate. The problems involve development of insensitive controllers for application to systems where the plant parameters are known only approximately. Also required are new system identification

methods for adaptive control systems where the parameters can vary significantly with time. Investigations will be performed in the areas ofmultivariable control systems dealing with uncertainty, robustness and sensitivity using frequency domain tools. Work will continue in the area of singular values and their use in determining stability margins. In adaptive control, research will be performed in the topics of caution and probing and their use in stochastic dynamic programming.

4. Controlled Vehicle Dynamics (RO 4.3.3): Develop improved theoretical models for accurately predicting pressure distribution over three-dimensional wings. Using the modified Smith model as a basis, investigate the effects of vortex shedding (both symmetric and asymmetric) and vortex bursting on the pressure distribution over slender delta wings. Acquire an understanding of the physical processes and mathematical aspects that prevail when aerodynamic characteristics are not uniquely defined by geometric parameters and local flow conditions. Continue research on the causes, characteristics, and consequences for flight control of aerodynamic hysteresis. Current mathematical models will be used, and refined as necessary, to determine under what conditions the separation and reattachment processes differ and the nature of these differences. Investigate the aerodynamic and dynamic issues fundamental to the supermaneuverability concept. Ascertain the importance of non-stationary initial conditions and define the accuracy with which nonlinearities must be determined and considered. Investigate time-dependent characteristics of aero-dynamic forces and moments, which are functionals of the state variables, and attempt to develop exact representations of these functionals for use in the aircraft equations of motion. Analytically determine allowable error bounds to assess convergence and the identification of parameters, or groupings of parameters, which influence the stability of Volterra series solutions of the equations of motion.

5. Load Alleviation (RO 4.3.4.): Develop basic new mathematical models for describing, analyzing and synthesing controllers for general systems. Research is required to produce methodology for the identification, control and synthesis of flight vehicles, using existing or proposed subsystems and components, to meet overall system configuration and performance specifications, and for the analysis and testing of the resulting flight vehicle design. This work will make use of some recent results in mathematical systems theory, involving topics such as controllability, observability, and realizability, which have been treated by state space and frequency domain methods in the last ten years. New methods in nonlinear estimation will be developed for use in adaptive control systems. Design methodology will be extended and simplified for use in robust control algorithms and devices. New aerodynamic models will be used to design control and identification techniques.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Design aircraft control systems for piloted aircraft configured with new aerodynamic control surfaces yielding more flexible operation.

b. Design aircraft with enhanced maneuverability, improved structural load distribution, and better handling and ride qualities.

c. Develop the numerical/computational capability for solving nonlinear control problems, control problems with random disturbances and delays and distributed parameter control problems.

d. Design aircraft control systems assuring relatively fixed stability throughout the flight regime.

e. Better understand parameter models of aeroelastic systems and flexible structures.

f. Design turbulence-tolerant aircraft for longer airframe life and active controls for flutter suppression.

g. Minimize the proliferation of costly redundant hardware currently needed to insure reliability.

h. Develop control policies for large space structures, space based weapons and satellites.

i. Exploit new control concepts to provide more responsible and stable aircraft control, more reliable control of weapons and improved maneuverability of new aircraft.

j. Provide guides to research in appropriate techniques for algorithms and criteria for future military aircraft that improve fuel efficiency without degrading performance, that are computationally feasible and that take advantage of new results in control.

k. Provide the methodology to exploit new technologies of aircraft design and computational capabilities to enhance the fuel efficiency of these new systems, to dsign numerical algorithms for accurate digital control and identification of adaptive systems.

SUBAREA 4.3 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 4.3 ($K)
2304A1	Mathematics of Dynamics and Control	2250	450
2304A5	Statistics and Probability	3100	275
2304A8	Mathematical Optimization	900	300
2304N3	Mathematics of Flight Control Systems	50	50
2307N3	Dynamics of Aerospace Vehicles	250	250
	TOTAL		1325

AFOSR MANAGER: Dr Michael J. Salkind
Telephone: (202) 767-4987

TECHNICAL AREA 5: Propulsion and Power

INTRODUCTION

Air Force missions require propulsion for aircraft, missiles, and spacecraft, and power generation, storage, and transmission. The jet engine is a key element of our air superiority and only through pushing the state-of-the-art in compressor fluid mechanics, combustion technology, fuels, cooling, structural dynamics, and turbine materials have we maintained superiority over our adversaries. In missile propulsion, we need to enhance both payload and range capability but avoid detectable plumes, short storage life, and system hazards. Also our choice of propulsion approaches must be broadened to provide the flexiblity to accommodate an increasing number of mission envelopes. For orbit raising, many-fold improvements in propulsion system efficiency are required to enable many of the large payload missions. The key science issues are an understanding of combustion, including instability suppression, improved propellants, and structural interactions all coupled with advanced diagnostic techniques. Power research is diverse. We have limited power requirements for aircraft because of their powerful gas turbines. By contrast, we have a wide range of power requirements for spacecraft, which must generate and store power and manage waste heat within severe weight limits. These requirements imply that we need diverse power generation concepts ranging from photovoltaic devices to energy conversion from nuclear systems. Thermionics offer promise of efficient power sources that can be throttled to satisfy propulsion, station keeping, and mission needs. Energy storage requirements revolve around electrochemistry with thermomechanical devices on the horizon. Thermal management requirements relate to conduction, exchange, and radiator systems and attendant thermodynamic and fluid mechanics science issues.

This technical area plan is organized into three subareas: Rocket Propulsion, Airbreathing Propulsion, and Power. Contributing substantially to these subareas are the FY 82 initiatives in Space Propulsion and Power and the FY 85 initiatives in Gas Turbine Hot Section Research. These initiatives are interdisciplinary and major elements of each have been incorporated into the three subareas of this technical area.

Emphasis continues on developing and using nonintrusive diagnostic techniques in combustion and plasmas. New capabilities developed in this program have provided substantial new insights into the fundamentals of reacting flows and have been applied in cruise missile and aircraft propulsion systems. The current rocket propulsion activity will provide options for higher performance orbit-raising and station keeping propulsion technology for spacecraft. In airbreathing propulsion, we will concentrate on fuel spray and combustion fundamentals, soot generation, compressor aerodynamics, and structural dynamics. New considerations in transatmospheric propulsion will introduce additional research challenges to achieve the sequential propulsion cycles required for single stage to orbit vehicles. The approaches to be considered include propulsion for horizontal takeoff, supersonic airbreathing propulsion, air-augmented rockets, and external burning.

FY 86 PLANNED FUNDING:

SUBAREA NUMBER	TITLE	FUNDS SPTG SUBAREA ($K)
5.1	Rocket Propulsion	6447.5
5.2	Airbreathing Propulsion	11395.7
5.3	Aerospace Power and Energy	2723
	TECHNICAL AREA TOTAL	20566.2

AFOSR Focal Point: Dr Leonard H. Caveny
Telephone: (202) 767-4937

TECHNICAL AREA: Propulsion and Power

SUBAREA NUMBER AND TITLE: 5.1 Rocket Propulsion

GENERAL OBJECTIVES: Research in support of rocket propulsion is directed at enhancing the capability of chemical propulsion, providing a fundamental basis for a new generation of space propulsion concepts, and improving the scientific understanding of phenomena associated with the generation of propulsive power. Research is needed from molecular to macroscopic scales in areas which include plasma acceleration, dynamics of rocket combustion, the behavior and synthesis of advanced energetic materials, characteristics of exhaust plume formation and radiation, and the processes of advanced propulsion concepts. This knowledge is needed to meet mid-term and long-term Air Force technology goals related to improving performance, reliability, penetrability, and durability for Air Force mission applications involving space systems, ballistic missiles, and air launched missiles. However, specific provisions are also included for research directed toward scientific opportunities which cannot be related to particular mission areas at this time.

Future Air Force space missions for communications, surveillance, and weapons systems will require substantially higher power density and greatly improved propulsion. Research is expected to lead to improvements of 20% in propulsion efficiency with improved liquid and solid propellants and 100 to 200% with non-conventional systems such as electromagnetic plasma acceleration and energy beaming, magnetoplasmadynamics, and nuclear power propulsion.

RESEARCH EFFORTS:

1. Solid Mechanics (RO 5.1.1): We seek to improve the understanding and prediction of fracture and crack growth through improved solutions to the nonlinear constiutive equations and through approaches such as photoelasticity and the method of caustics. In particular, a failure criterion under finite deformation is being developed. Theoretical age-life models are being based upon chemical reactions of multi-ingredient composites. Research on aging suppression by means of chemical influences is being expanded. In support of the continuing need for improved carbon-carbon components, research is being conducted to understand the bonding mechanism between carbon fibers and the matrix material using vapor deposited carbon layers.

2. Noninterfering Diagnostic Techniques (RO 5.1.4): Our present research is advancing diagnostic techniques for measuring the gas and gas-particle flow properties representative of rocket systems including plumes. In addition, the research is tied to the Air Force chemical laser and power generation requirements. Diagnostic techniques are being conceived to obtain rapid and quantitative spatially and temporally resolved measurements of temperature, pressure, velocity, species concentrations and densities, and particle/droplet

size distribution in optically dense, high-temperature reacting, unsteady, turbulent flowing media. New emphasis is being placed on techniques suitable for operational propulsion systems as well as techniques for systems for laboratory research. Where necessary, fundamental physical parameters needed to implement the techniques are being determined. Both tunable dye and diode laser absorption and emission spectroscopy are being extended to include additional species, optical probes, time dependent flows, and particle-laden flows. Fiber optics used in conjunction with several diagnostic methods are being advanced as means of probing hostile flows. Quantitative flow visualization is being extended using laser illumination of planar regions. As tests of technique suitability, the following physical situations are being investigated: turbulent reacting, shear layer flow to understand the coupling between fluid dynamic and chemical processes; droplet evaporation in turbulent flows; flows with high particle loadings; and plasma flows. Recently research is defining the sensing strategies which will enable adaptive control and autonomous operation of high performance propulsion systems.

3. Exhaust Plumes (RO 5.1.2): The goals of this research include providing mechanistic basis for analyzing, interpreting, and altering plume radiance. The research is establishing the influence of composition and flow environment on gaseous species and particle formation. New research is addressing the mechanisms of exhaust plume/air igntion in the presence of flame suppression additives. Gaseous simulations of rocket exhaust products are being used to determine species and temperature changes produced by introduction of suppressant additives. The mechanisms responsible for plume radiance in the uv and ir spectral regions and plume contamination are being examined. Pico-second excitiation techniques are being explored to establish the potential of photon-echo signals to provide information on molecular transport phenomena. New research activity addresses the plumes of electrical propulsion systems for the purpose of understanding conditions that can lead to spacecraft contamination. Collisional physics models are being developed to understand free jet expansions and to evaluate the validity of concurrent experiments.

4. Solid Propellants and Energetic Materials (RO 5.1.3): The primary objectives are to synthesize energetic ingredients leading to tough, high energy propellants with desireable properties which include low glass-transition temperatures, high thermochemical stability temperatures, high solid loadings, and smokelessness. A portion of the research seeks to control the behavior of energetic materials during combustion by establishing relationships between molecular structure and decomposition and combustion processes. Synthesis and chemical reactivity of high energy nitrogen-fluorine compounds, polynitro organics, and tetrazine derivatives are being investigated. Stable isotope labelled oxidizers will be synthesized for use in decomposition mechanism studies. Scale-up synthesis of promising energetic monomer ingredients is being improved for subsequent polymerization studies. Specific aspects of the principles of diepoxide copolymerization modification are being investigated. Investigations include energetic glycidyl deriviatives, poly-DNPVE modification, and other monomers that potentially produce polyether structures. Investigations will be conducted on xenon difluoride chemistry for new fluorination transformations, with triflate intermediates.

5. Combustion and Reacting Flows (RO 5.1.4): Combustion and reacting flow research is the central part of this subtask. Several of the current research projects are directed at understanding important bond rupture and heat release mechanisms so that research to modify burning rate and combustion efficiency can be directed at specific reaction sites. Methods are being pursued for obtaining the key reaction parameters for energetic materials being heated at rates in excess of 10^4K/s. Of particular concern is the characterization of the mechanisms leading to changes in solid propellant properties and burning modes that produce transition from normal deflagration to detonation of rocket motor grains. A continuing activity increases the scope and usefulness of standard rate data and the JANAF Thermochemical Property Data. Thermal properties of energetic materials (GAP, HMX and RDX) are being determined using Fourier transform rapid scanning techniques devised for decomposing materials. Techniques are being established to follow the rapid temperature increases, compositional changes, and phase changes that occur within a decomposing energetic material. Combustion mechanisms in the flow field adjacent to the fuel rich surface are being modelled for the purpose of understanding the coupling between the flow field and the uniform surface regression processes. Advanced diagnostic techniques are being employed to determine reaction pathways above the surfaces of HMX and AP propellants.

6. Combustion Instability (RO 5.1.4): Through this research we continue to improve techniques for interpreting, predicting, and avoiding unstable behavior in solid motors through mechanistic understanding of contributions such as nozzle damping, acoustic erosivity, pressure coupling, vortex streaming, vortex sheading, distributed combustion, particle and structural damping, and high velocity effects. More complete theoretical formulations are accounting for the significant effects of 2-D and 3-D geometries. We are particularly interested in approaches to defeat combustion instability by purposely dissipating acoustic energy in prescribed modes and to examine more direct means of measuring acoustic admittance. Attention will be focused on how acoustic excitation can affect turbulence levels at the wall. New activity is seeking arationale for configuring chambers which will defeat specific acoustic modes and the dissipation of acoustic energy via burning metal oxide particles. Experimental work is being directed at understanding how combustion response and flow field parameters can be obtained more reliably in laboratory devices and rocket motors. Particular attention is being given to the interactions among the mechanisms by which vortex energy is transformed into acoustic energy, the infuluences of acoustic fields on shear layer instability, and the mechanisms by which energy is transferred between an acoustic field and mean flow entering through the cavity boundaries. The extent to which ammonium perchlorate ignition delays and particle size distributions influence the mean and transient responses of wide distribution propellants is being examined.

7. Metal Combustion (RO 5.1.4): Research is being conducted to characterize the basic mechanisms and chemistry involved in metal combustion and the formation of metal oxide particulates. Experiments are being conducted to determine physical and chemical processes leading to the acceleration of metal droplet ignition and combustion. One of the goals is to greatly reduce the size of metal oxide agglomerates entering nozzle convergent sections. Research is being conducted to improve methods for simultaneously measuring

temperature and concentration of turbulent flame zones so that conditions leading to metal combustion under ram-rocket conditions (particularly high altitude) can be characterized. Experiments are being conducted to assess the role of fluorine in the combustion of fluorinated metallic propellants and to determine mechanisms that affect oxide particle size. Experiments are being conducted to characterize the high temperature kinetic processes controlling ignition and combustion of metal fuels. Work will continue toward developing new and revised JANAF Tables with emphasis on metal compounds and fluorine compounds.

8. Beamed and Solar Energy (RO 5.1.5): The goals of this research are to quantify mechanisms of radiant energy transfer to working fluids, to assess the barriers to optical access for energy transmission, and to establish approaches to plasma confinement. Experiments are underway to explore the capability of a solar furnace and flow reactor apparatus to characterize solar energy absorption in flowing seeded-hydrogen plasmas. Experiments are characterizing the absorption of laser energy in flowing plasmas and accounting for phenomena such as bleaching at elevated temperatures.

9. Electromagnetic Acceleration (RO 5.1.5): Research is underway to understand magnetoplasmadynamic processes for the purposes of establishing the conditions of sustained high energy density operation and to project upper limits of power density. Primary objectives include: to establish the conditions and materials leading to extended electrode life, to produce stable magnetoplasmadynamic flows for sustained high energy density operation, to decrease the losses in thermionic flows, and to explore novel approaches to high energy density storage. Electromagnetic confinement is being analyze as a means of accommodating plasma temperatures greatly in excess of material limits. Coordinated experimental and theoretical approaches are categorizing the interactions between plasma flow fields and surfaces in terms of multicomponent transport mechanisms and material loss mechanisms. Investigations are considering both self and imposed magnetic fields. Discharge plasmadynamics flow regimes are being modelled by accounting for momentum in instability analyses and establish stable flow conditions leading to reduced elecrode wear. Multidimensional plasma flow models are being developed to account for anode region instabilities, electrode hot spots, and non-uniform flows. Experiments are being conducted to explore the couplings between a flat inductor and a thin metal sheet to establish the mechanisms of acceleration and vaporization. Research for thermionic converters is exploring the mechanistic limits to achieving 5 to 10 micrometer spacing at low pressures as a means of reducing losses due to collisions. Transport mechanisms in the thermionic non-ignition mode are being modelled to understand the region of low arc-drop operation hypothesized to be a result of reflection of positive ions by emitter sheaths.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Enable consideration of rapid positioning of large space payloads.

b. Increase the reliability of rocket performance predictions.

c. Increase the ability to avoid and to suppress rocket motor instabilities.

d. Reduce the detectability of missiles by reducing the visible smoke produced by the rocket motor.

e. Provide accurate plume models and plume data analyses from both the surveillance and avoidance points of view.

f. Provide capability to avoid hazards of solid rocket motors.

g. Increase the number of propellant options available to system designers.

h. Improve the capability for service life prediction for solid rocket motor grains and structural interfaces.

SUBAREA 5.1 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS (K)	TASK FUNDS SPTG SUBAREA 5.1 (K)
2302M1	Fracture Mechanics and Service Life Prediction	370	370
2303B2	Chemical Reactivity and Synthesis	2905	685
2303F3	Energetic Materials Chemistry Research	285	85
2303M1	Synthesis and Mechanism Propellant Ingredients	510	510
2306M1	Nozzle Material Technology	179	179
2308A1	Rocket Combustion Dynamics	3173	3103
2308A3	Diagnostics in Reacting Media	1200	587.5
2308M1	Combustion Technology	300	300
2308M2	Plume Technology	366	366
2308M3	Non-Conventional Propulsion	262	262
	TOTAL		6447.5

AFOSR Focal Point: Dr Julian Tishkoff
Telephone: (202) 767-4935

TECHNICAL AREA: Propulsion and Power

SUBAREA NUMBER AND TITLE: 5.2 Airbreathing Propulsion

GENERAL OBJECTIVE: The research in this subarea will provide the scientific capability to improve the performance of propulsion systems for aerospace vehicles and weapon systems which fly through the earth's atmosphere. In these propulsion systems ambient air is inducted into mechanical components, thermal energy is added through combustion, and the mechanical energy of propulsion is produced through a conversion process. Current aircraft utilize gas turbines for propulsion. For future missions at higher supersonic Mach numbers both subsonic and supersonic combustion ramjets are under study. Mission capability extending to a transatmospheric vehicle (TAV) will be possible as a result of this research activity. Corresponding increases in flight speeds will go from current limitations of Mach 3+ past Mach 25, and altitude performance will reach the threshold of space. Other technological benefits will include improved component durability, reduced design and development cost and capability for utilizing high-energy density fuels. Research disciplines include fluid mechanics and aerothermodynamics for efficient utilization of the airflow in propulsion and heat transfer; structural mechanics and aeroelasticity for engine components which exhibit durability with respect to static and dynamic stressing; and combustion to achieve efficient fuel utilization with minimum adverse effects from the exhaust products on heat transfer and detectable exhaust signature.

RESEARCH EFFORTS:

1. Fluid Dynamics and Aerothermodynamics (RO 5.2.1) - We seek to illuminate and quantify the behavior of compressible viscous flow in internal passages of varying cross-section and curved centerlines. The studies should advance the understanding of such phenomena as shock-boundary layer interactions and the mixing of flows with strongly varying stagnation properties, including the effects of secondary flows and possibly of swirl and high curvature. Improved methods for modeling flow unsteadiness and turbulence effects are sought. We shall improve the accuracy and computational efficiency of 3-D inviscid flow analysis and develop models capable of identifying and quantifying the losses associated with 3-D flow interactions within compressors and turbines. Examples of such interactions would include the horseshoe vortex, the passage vortex, tip leakage, end wall secondary flows and the effect of subsequent mixing of the developed 3-D flows. The effect of time dependent fluctuations on loss mechanisms including wake influences on boundary layer losses, as well as time dependent potential flow interactions, is sought. The validity of turbulence models in flows with large rotation and curvature is to be established. Methods to incorporate numerical or simplified versions of 3-D loss mechanisms into design codes are to be developed. Experimental and analytical clarification of the mechanism of rotating stall is sought. We shall identify and quantify the principal viscous effects present in three dimensional compressor flow fields and develop the means to account for them in design and analysis codes. An approach to compressor design taking into account the nonsteady effects associated with multistaging will be

formulated. We shall increase the qualitative and quantitative understanding of the effect of free stream turbulence on turbine heat transfer, establish the effect of wake interaction and flow unsteadiness on turbine heat transfer, and determine the influence of end wall boundary layer state and blade tip clearance heat transfer. Related predictive models will be formulated. Measurements will be made in cool combustors to characterize the turbulence properties of both model and actual full scale combustors in which the high and low temperature properties are characterized by fluids of the appropriate densities. From measurements in shock tubes we shall obtain heat transfer data. Seeding techniques, transient data acquisition and window treatments for laser velocimeter applications will be developed. A time-dependent numerical simulation will predict the interaction of periodic disturbances with a laminar boundary layer.

2. Structural Mechanics (RO 5.2.2) - We shall formulate a boundary integral equation method of analysis including inelastic material response valid for investigating fatigue crack growth behavior to study plasticity effects such as plastic wake, overload, and crack closure. Short crack growth will be modeled as a discrete step stochastic growth process, including microstructural effects such as grain size and orientation. A fundamental combined theoretical/experimental effort on thermomechanical fatigue will be initiated. We are investigating and modeling the three-dimensional dynamic response and stability of turbomachinery components with particular emphasis on geometric and material nonlinearities associated with rotor bearing stiffness and damping, friction dampers, and coupled blade/disk interaction. Rotating stall and surge, blade row interaction, and shock and choke phenomena are under study. The aeroelastic transient response and stability of rotating components with emphasis on the effects of seal and bearing loadings will be determined. We are investigating the effects of structural mistuning of rotor blade rows, nonaxisymmetric flows and their mutual interactions, taking into account the statistical nature of mistuning patterns.

3. Combustion and Reacting Flows (RO 5.2.3) - Experimentation to achieve fundamental understanding of turbulent reacting flow will be undertaken and well-characterized conditions in shear layers, jets, stagnation flow fields and V-flames. Prediction methods for combustor processes which are free of approximate models are beyond current computer capability, so formulations must be tested against simplified configurations such as the experiments which have been described. Predictions will be based on solutions of three-dimensional, transient transport equations for mass, momentum, energy and chemical species. Theoretical analysis of interactions among vortices and between vortices and walls will be undertaken as an important component of understanding the coupling between fluid mechanics and chemistry in combustion. In the near term, computational limitations will necessitate the continued use of time-averaged models. These models will be improved to predict the counter-gradient diffusion phenomenon commonly found in combustors by utilizing conditional sampling methods. Improved closure models including finite-rate chemistry will be formulated based on probability density functions. Supporting experimentation will be conducted utilizing combinations of measurement techniques for fluid mechanical, thermodynamic and chemical variables. While the advanced simulation methods are excessively complex for current combustion system design and development, they will play a significant near term role as numerical experiments - predictions of simplified turbulent reacting flows without modeling approximations which

provide complete detailed data beyond the measurement capabilities in physical experiments for the validation of engineering models. Unbiased laser velocimeter measurements in turbulent, recirculating flows and simple combusting flows will test the accuracy of current turbulence models. Multi-stress models for 2-D and swirling flows will be formulated and validated with the experimental data. Subgrid turbulence models will be added to a time-dependent prediction of nonreacting turbulent, recirculating flow. Temperatures, velocities and turbulence intensities will be measured for lifted jet flames burning different fuels. These data will be compared to different theories of flame lift-off to determine which is most correct. Two velocity components and temperature can be measured virtually simultaneously by combining laser velocimetry with coherent, anti-Stokes Raman spectroscopy (CARS). High-speed movies will show turbulent mixing, as indicated by laser-sheet light scattering from minute seed particles. The physical and chemical conditions affecting soot formation and growth within combustors will be determined. Adverse effects on both the durability of propulsion components and detectable exhaust signature will be investigated. This research is also relevant to effort 5.2.4. Both theoretical and experimental approaches will be applied to the phenomena of fuel atomization and nondilute spray behavior, in which closely spaced droplets exert strong mutual interactions. Parallel, yet physical distinct, research must be performed for liquid and slurry fuels. The effects of physical properties, state variables and flow field velocity and turbulence on the breakup of liquid jets in high-speed cross flows will be investigated. The prediction of combustion instability onset utilizing linearized analysis will be improved by the incorporation of energy release based on vortex combustion. Experimental investigtions of the interactions among fluid mechanics, acoustics and combustion chemistry which cause instability will be continued in a model ramjet dump combustor configuration. We seek to provide understanding of physico-chemical combustion processes required for the design and development of hypersonic airbreathing propulsion systems. The interactions between compressibility and multiphase, turbulent reacting flow will be studied. Efficient combustion in very short time durations must be achieved. We shall develop computationally tractable prediction methods for the rates of energy release and chemical product formation for complex hydrocarbon molecules and molecular mixtures under turbulent premixed and nonpremixed combustion conditions. The chemical reaction mechanisms for the combustion of high energy density alternative fuels such as boron slurries will be studied. Measurement capability is requested for flow velocity, temperature, chemical species, density and pressure with temporal and spatial resolution down to the relevant turbulence microscales. Measurement of particle size and velocity for both soot and fuel droplets also will be developed and utilized in this research. Point measurements include laser velocimetry and coherent anti-Stokes Raman spectroscopy. Two-dimensional quantitatve imaging produces species and temperature data utilizing laser-induced fluorescence. Three-dimensional data will result from holography and tomography. Novel approaches such as photoacoustic/photothermal methods, optical probes and asynchronous optical sampling are being explored. Corrections for biasing of laser velocimeter data resulting from nonuniform distribution of seeding particles are being developed.

4. Signature (RO 5.2.4) - A kinetic reference data project will continue to provide tabular data of combustion reactions in the JANAF Thermochemical Tables relevant to exhaust emissions.

5. Propulsion Controls (RO 5.2.5) - Sensor requirements for dynamic control of combustion in operating propulsion systems differ fundamentally from those for laboratory instrumentation. Because excessively large combinations of measurements could be made in plasmas or reacting flows, research will be conducted to model these processes from a control theory perspective in order to determine which measurements are critical to the control strategy.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Ascertain significant aeromechanical phenomena to be incorporated into improved analytical models of bladed disks.

b. Provide the analytical tools to predict the aeromechanical response and durability of advanced bladed disk systems.

c. Develop diagnostic techniques for definition of the hostile turbine engine environment.

d. Provide analytical tools to develop improved aircraft turbine engine, ramjet engine and ducted rocket combustors.

e. Provide validated combustion models that include fuel chemistry effects. These models can be used to help optimize jet fuel specifications.

f. Reduce the amount of expensive testing required to develop ramjet engines.

g. Expand the operating envelope for airbreathing aircraft and missile systems.

h. Provide improved diagnostic techniques for identifying abnormal particle wear prior to engine/component failure.

i. Provide basis for design of combustors with less detectable jet exhaust plume characteristics.

j. Evaluate potentials of advanced high energy-high density and new synthetic (coal, shale oil) hydrocarbon fuels.

k. Provide a sound, scientific basis for designers of advanced engines to reliably predict and avoid aeroelastic instabilities.

l. Provide basis for design of turbine and compressor blading to avoid stall and separation and aeroelastic flutter failure.

m. Reduce propulsion system maintenance costs.

n. Increase engine durability.

o. Achieve significant gains in supersonic gas turbine-powered flight by increasing the combustor exit temperature.

p. Produce sensors and logic for a full-authority engine digital control system.

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SUBAREA 5.2 FY86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	SPTG SUBAREA 5.2 ($K)
2301S1	Advanced Optical Measurement Techniques	658	474.2
2302B1	Mechanics of Structures	2800	400
2302B2	Structural Durability	3352	293
2302S2	Aeromechanical Response in Airbreathing Propulsion Systems	270	270
2303A1	Chemical Techniques	1303	293
2304A1	Mathematics of Dynamics & Control	2250	175
2307A4	Internal Fluid Dynamics	2400	2310
2307S1	Turbomachinery Fluid Mechanics	1040	1040
2307S3	Turbine Aerothermal Research	308	308
2308A1	Rocket Combustion Dynamics	3173	40
2308A2	Airbreathing Combustion	4050	4050
2308A3	Diagnostics in Reacting Media	1200	612.5
2308S1	Ramjet Research	780	780
2308S7	Combustion Research	350	350
	TOTAL		11395.7

AFOSR Focal Point: Maj Bruce L. Smith
Telephone: (202) 767-4908

TECHNICAL AREA: Propulsion and Power

SUBAREA NUMBER AND TITLE: 5.3 Aerospace Power and Energy

GENERAL OBJECTIVE: This objective is related to electrical power for manned and unmanned aircraft, satellites and space stations; thermal batteries for aircraft, conventional weapons and munitions; as well as electrical power for unattended ground based systems. Future ground and space based weapons systems may require power levels from tens to hundreds of megawatts; and research is required in the generation of usable electrical power from radiant, chemical and nuclear sources, distribution and conditioning of the power and the attendant material requirements. Energy conversion schemes which require additional research include batteries, fuel cells, solar cells, MHD generators, direct thermal to electrical conversion, and dynamic conversion systems. Research is also required in the area of thermal management associated with space based power systems for which heat rejection becomes the pacing issue at higher power levels.

RESEARCH EFFORTS:

1. Energy Sources (RO 5.3.1): Research to improve the energy density, specific power, and total power of solar, nuclear, and chemical energy sources is needed. Mechanisms of fuel swelling and other high temperature material interactions in a radiation environment must be understood to enable multimegawatt space nuclear power. Determine the mechanisms of high temperature cavity swelling of refractory metals in a radiation environment.

2. Direct Energy Conversion (RO 5.3.2): Research is needed to understand the fundamental limits in terms of specific power and conversion efficiency imposed on photovoltaic, thermionic, thermoelectric, and magnetohydrodynamic energy conversion processes and to explore the potential of new direct conversion processes. Theoretical predictions for the stability and energy density limits of high interaction MHD flows must be confirmed experimentally. Perform benchmark measurements of high interaction MHD flows to confirm predicted magnetoaerothermal and magnetoacoustic instabilities in high enthalpy extraction and specific power MHD flows. Produce films with graded composition dictated by theory for graded bandgap seminconductors to match the spectral characteristics of radiant sources. Establish the mechanisms which determine maximum conversion efficiencies of graded bandgap structures.

3. Dynamic Energy Conversion (RO 5.3.3): Superconducting generators can be improved both by understanding magnetic flux motion and associated losses in Type II superconductors and by learning how to tailor the heat capacity and thermal transport characteristics of coatings which would stabilize the superconductor during rapid heating transients. Field induced phenomena in insulators at high fields and high field gradients must be understood to insure reliable, long lived space power systems. Explore the potential of new alkali halide-like crystals and a new class of refractory oxides for enthalpy

improved dielectric insulation for superconductors. Determine the time varying electromechanical and partial discharge processes resulting from high electric fields and field gradients in insulators and develop a theory of insulator breakdown at high frequencies and power.

4. Energy Storage and Conditioning (RO 5.3.4): Research is needed to explore novel high energy density and high total energy storage media as alternatives to direct conversion of solar, nuclear, or chemical energy to multimegawatt power levels. The predicted advantages of inductive energy storage over capacitive storage must be realized by improved characterization of material properties of superconductors and by exploiting novel concepts such as densification of electron clouds via traveling magnetic wave acceleration. Provide scientific basis for the development of high current density and high energy density electrochemical power supplies. Investigate new electrode/electrolyte systems for high energy density and long storage life for batteries. Determine performance-limiting and life-limiting mechanisms associated with contemporary electrochemical batteries. Extend concepts on thermally activated batteries. Exploit auxiliary batteries based on fused salt systems. Investigate effects that limit electrode life and look for cell additives that can extend cycle life. Elucidate the fundamental chemical and electrochemical reactions occurring within cells. Study the electrochemistry associated with very high current discharge (for short time periods) delivered by either primary or rechargeable batteries. Explore the electrochemical aspects of lithium rechargeability in combination with various potential cathodes. Heterogeneous electron transfer kinetics, adsorption thermodynamics, and surface-enhanced Raman scattering (SERS) measurements will be used to investigate the mechanisms of how the adsorption of complex compounds on metal electrodes influence electron transfer. Surface tension measurements by computer controlled maximum bubble pressure apparatus and activity data from EMF measurements will be utilized to determine the effects of organic adsorbates on the electrolyte. Physical and electrochemical studies of novel room temperature liquid salts based on copper will be undertaken. Ambient temperature chloroaluminate ionic liquids and related systems will be explored, along with associated electrochemical techniques. Perform research on low-melting molten salt electrolyte systems and compatible battery components. Active metals such as aluminum, lithium and a variety of active cathode materials are under investigation. Construct and test electrochemical cells using low-melting molten salts. A variety of anode and cathode materials and reduction-oxidation couples will be investigated, as well as various additives to increase electrical conductivity. Studies will be conducted to improve the performance and life of the nickel hydroxide electrode. The relationship between the mechanical properties of the electrode (substrate and nickel active material) and the electrochemical characteristics during electrical cycling will be investigated. Electrodes with uniform mechanical/electrical properties will be studied as a means of producing cells with extended cycle life at higher depths-of-discharge. Migration inhibiting agents will be studied. Non-aqueous electrolyte primary and secondary cell anodes of lithium will continue to be studied by use of electron microscopy, and ESCA as a function of time and temperature. Investigate rate limitations, cut-off voltage restrictions, lithium rechargeability, electrolyte involvement and thermal control for ambient temperature rechargeable non-aqueous cells. Synthesize low temperature molten salts and evaluate candidate electrodes by use of standard electrochemical

techniques. The electrochemical of polymer electrode materials will be studied to determine the rate limiting process as a function of the degree of dopant. Work will continue on the study of non-aqueous electrochemical couples which offer the potential for extremely high discharge rates for short time periods coupled with normal operation at very high energy densities. The problems associated with high rate electrochemistry will be analyzed and investigated in experimental cells.

5. Thermal Management (RO 5.3.5): More weight efficient and less vulnerable heat rejection concepts must be realized to overcome the cooling limitations on continuous operation at tens to hundreds of megawatts (electrical). Investigate combined heat and mass transfer phenomena applicable to steady and pulsed power spacecraft radiators and thermal protection of spacecraft. Investigate steady and unsteady heat transfer mechanisms in two-phase fluid flow and thermal storage media applicable to high transport capacity (greater than 10 kW-m), high heat flux (greater than 100 kW/m^2), and/or pulsed power (greater than 100/1 peak/average) heat rejection applications. Explore the potential of active cooling concepts. Establish a comprehensive, mechanistic model for droplet cloud motion and radiation. Complete the development of a distributed parameter radiant-convective heat transfer theory for free and confined particulate, droplet, and/or vapor transport media, with and without phase change in the transport media. Experimental verification of transport and surface tension enhanced heat transfer theory mechanisms will continue. Continue development of unsteady heat transfer theory in countercurrent and co-current capillary augmented two phase heat transfer processes. Extend current radial flow condensation heat transfer investigations to include pressure, density, liquid-vapor meniscus radius of curvature and shear force axial variation influences on local heat transfer rates for application to both expandable or thin film radiator concepts and two phase transport devices.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Develop new solid electrode systems coupled with new high voltage/high discharge rate electrodes for advanced munitions and life support equipment.

b. Lengthen satellite missions because of improved photovoltaic solar cell lifetimes and efficiencies.

c. Fulfill the priority requirement for new thermal batteries in missiles, munitions, and ECM systems.

d. Develop better design of, and improve applications of, advance alkaline electrolyte rechargeable batteries with exceptional storage life.

e. Improve spacecraft electrical power and thermal management subsystems.

f. Bring about multimegawatt prime electrical power systems for future based directed energy weapons and surveillance systems.

SUBAREA 5.3 FY 85 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 5.3 ($K)
2301A7	Space Power and Particle Beams	3900	1400
2303A1	Chemical Techniques	1303	495
2303F2	Physical Chemistry and Electrochemistry	180	180
2303S4	Electrochemistry	483	483
2308S8	Spacecraft Energy and Thermal Management Research	165	165
	TOTAL		2723

AFOSR MANAGER: Col Hugo Weichel
Telephone: (202) 767-4904

TECHNICAL AREA 6: Weaponry

INTRODUCTION

The ultimate objective of much of the Air Force's mission is to be able to locate and destroy targets. An improvement in this capability enhances the Air Force's effectiveness. The weaponry research program supports basic research in developing more effective destructive mechanisms and in mitigating the effects of enemy military weapons so that future systems can be designed to be less vulnerable.

The ability of weapons systems to survive in a nuclear conflict is essential for maintaining a credible deterrence. However because nuclear weapon testing is very limited, a need exists to develop devices that simulate the thermal and electromagnetic radiation effects of nuclear detonations. These devices permit examining and validating the survivability of weapon systems in a nuclear environment.

Conventional warfare will continue to be extremely important to the Air Force's mission. A need exists to increase the destructive capabilities of conventional weapons by developing explosives that are more reliable, less sensitive, more powerful per unit weight, and less expensive. More efficient and effective methods for delivering weapons to targets are also important.

Directed energy technology offers the possibility that the use of radically different weapon systems, such as high energy lasers, particle beams, and attendant power systems, will become practical within the next one or two decades. Research will provide the basis for developing these systems and for examining the feasiblity of other technological possibilities.

The effects of combat on Air Force facilities will also greatly affect the survivability of strategic structures. The repair of tactical and logistic aircraft launch and recovery surfaces, the methods and equipment for avoiding damage, and the requirements for maintaining and repairing Air Force real property facilities need continuing emphasis.

The environmental effects of weapons systems must be considered when developing and using these systems. Understanding and attacking pollution and other environmental effects must proceed at the same time as system development.

FY 86 PLANNED FUNDING:

MAJOR THRUST INITIATIVE:	FUNDING ($K)
Laser Physics	400
TOTAL	400

SUBAREA NUMBER	TITLE	FUNDS SPTG SUBAREA ($K)
6.1	Nuclear Weapons Effects	1321
6.2	Conventional Weaponry	3046.5
6.3	Directed Energy Weapons	13522
6.4	Civil Engineering Technology	2935
6.5	Environmental Aspects of Weapon Systems	210
	TOTAL	21034.5
	TECHNICAL AREA TOTAL	21434.5

AFWL Focal Point: Dr L. A. Schlie
Telephone (505) 844-0883

TECHNICAL AREA: Weaponry

MAJOR THRUST INITIATIVE: Laser Physics

GENERAL OBJECTIVE: Presently there exist no efficient electrically excited visible/ultraviolet laser systems. Therefore large amounts of electrical power are required to deliver small amounts of power on target. Also, no high power chemical lasers exist that produce radiation in the visible region of the spectrum, that which is most easily propagated through the atmosphere. The objective of this initiative is to find more efficient and scalable electrically pumped laser systems in the visible/uv region and to develop a visible chemical laser by using Anti-Stokes Raman upconversion from the infrared.

RESEARCH EFFORTS:

1. Discharge Pumping of Inert Gas Mixtures: Both e-beams and microwaves will be used to excite inert gas mixtures to achieve the maximum and most efficient production of metastable species and the results will be compared with the theoretical analysis of these discharges. Information obtained from these experiments will be used to project the potential of these mixtures to excite various visible/uv laser systems.

2. Discharge Initiation of Chemical Reactions: Metastable species produced by discharges will be used to initiate and/or sustain chemical reactions in various gases possessing large internal chemical energies. Efforts to achieve highly effective electrical efficiencies in the visible/uv region will be emphasized.

3. Cross Section Data from Drift Velocity Measurements: Drift velocity of electrons in various gases will be measured as a function of applied E/N values and then, via detailed Boltzmann analysis of electron kinetics, cross sections for dissociation, electronic excitation, and ionization of gases will be determined.

4. Efficient Anti-Stokes Raman Media: Theoretical research will be conducted to develop methods to calculate Raman cross sections and percent conversion as a function of incident flux for metastable atomic and molecular species and to apply these methods to identify species with optical properties that are conducive to efficient Anti-Stokes Raman scattering. When promising systems have been identified, a detailed experimental approach will be defined. This will involve designing apparatus and diagnostics to produce the species at the requisite number densities and to measure cross sections and conversion efficiencies associated with Anti-Stokes Raman scattering.

FY 86 PLANNED FUNDING: $400K

AFOSR Focal Point: Dr Robert J. Barker
Telephone (202) 767-5011

TECHNICAL AREA: Weaponry

SUBAREA NUMBER AND TITLE: 6.1 Nuclear Weapons Effects

GENERAL OBJECTIVE: The detonation of a nuclear device releases a tremendous burst of radiation (both electromagnetic and thermal) as well as shock waves traveling through both air and ground with an admixture of any debris which may have been blasted loose from the ground. The individual ROs listed below seek to theoretically understand and, thereby, to be able to predict, simulate, and verify all of those effects in order to foresee and to minimize the impact of nuclear warfare on military installations and operations.

RESEARCH EFFORTS:

1. Low and High Altitude Nuclear Phenomena (RO 6.1.1): Develop new numerical techniques to simulate shock wave propagation in a computational mesh. Develop the mathematical analysis tools and numerical computational techniques for formulating and solving the mathematical models describing fluid flow phenomena. Develop the capability to determine experimentally and/or theoretically the final state product distributions of reactions involving atoms and moecules initially in either the ground or excited states. Specify the creation and dynamic evolution of atmospheric plasmas and their related chemistry in order to model nuclear effects on the propagation of communications and radar signals. Evaluate higher-order finite difference methods for inclusion in the AFWL nuclear weapons effects simulation code, HULL. Evaluate new solution methods, such as the Moving Finite Element (FME) method, for application to Atmospheric Nuclear Weapons Effects.

2. Transient and Thermal Radiation Effects (RO 6.1.3): Correct the errors that exist in the current AFWL HULL code dust and radiation models. Apply first principles in particle and nuclear physics to design new algorithms describing dusty flows and radiation/matter interations. Develop versatile algorithms to simulate thermal layer development without requiring nuclear event data as input.

3. X-Ray Effects (RO 6.1.4): Theoretical, numerical, and experimental studies will be conducted to characterize the physics of plasma and diode sources of x-rays which could be used to simulate nuclear weapons effects. Develop high intensity laboratory radiation sources with improved x-ray characterization capabilities including complete spectral, temporal, and spatial resolution of the radiation emitted by these devices.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Improved computer code calculations of atmospheric nuclear effects based upon improved knowledge of processes occurring in the atmosphere under perturbed conditions.

b. Knowledge of the final state product distributions of reactions involving atoms and molecules in the atmosphere following a nuclear burst.

c. Extend the predictive capability of the Air Force Weapons Laboratory code, HULL, beyond just atmospheric phenomenology to eventually include ground shock and cratering.

d. Adapt computational methods to support current advances in airblast simulation techniques, such as shock tube design and driver technology, as well as nonideal and precursor airblast simulation.

e. Techniques for predicting EMP/SGEMP interactions.

f. Radiation-producing plasma devices for use as nuclear x-ray simulators.

g. Mathematical models for transport phenomena, nonlinear wave propagation, and relativistic particle interactions.

SUBAREA 6.1 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 6.1 ($K)
2301A4	Atomic and Molecular Physics	1525	535
2301A7	Space Power and Particle Beams	3900	100
2301A8	Plasma Physics	3116	526
2304A3	Mathematics of Computation	3000	125
2304Y2	Nuclear Weapons Phenomenology	35	35
	TOTAL		1321

AFOSR Focal Point: Dr Robert J. Barker
Telephone: (202) 767-5011

TECHNICAL AREA: Weaponry

SUBAREA NUMBER AND TITLE: 6.2 Conventional Weaponry

GENERAL OBJECTIVE: Conventional weapons include all nonnuclear warfare devices which could be used to destroy or incapacitate enemy targets. The individual ROs listed below address the scientific understanding needed to advance the state-of-the-art in nonnuclear weapons and warhead/kill mechanisms. The continuing build up of Warsaw Pact armor in the NATO setting combined with revolutionary advances in "smart weapon" technology and the awesome scientific challenge of strategic missile defense has dramatically increased the urgency of research into conventional weaponry. The major scientific needs that have been identified thus far include the following: increased weapons platform standoff range, reduced signature, all-weather operations capability, autonomous target acquisition/tracking, major improvements in warhead effectiveness, and transonic/supersonic delivery (carriage and release of weapons). The individual ROs also address fundamental needs related to the integration of various components and subsystems such as propulsion, seeker, guidance, autopilot, control, fuze, warhead, and airframe. The costs of ownership of conventional weapons systems have been increasing in proportion to their growing complexity. Research is essential to help improve weapons performance levels while holding the line on acquisition and maintenance costs.

RESEARCH EFFORTS:

1. Guidance and Control (RO 6.2.1): Derive robust stochastic estimation methods that can provide highly accurate state information while maintaining sufficient bandwidth to adapt to abrupt target maneuvers. Improve performance of advanced guidance laws (at the expense of computational complexity) by incorporating a nonlinear model to describe the air-to-air intercept scenario. Develop new methods to identify a stochastic model of aircraft target dynamic behavior. Demonstrate the fidelity of the resulting model in a tracking filter and examine the resulting improvement in target state estimates. Explore the design of guided missiles autopilots with modern control methods. Investigate estimation techniques needed for realization of the autopilot robustness qualities required to insure stable and responsive airframe performance. Work will center on the currently unresolved issues associated with mode decoupling and output feedback.

2. Sensors/Seekers (RO 6.2.2): Examine the feasibility of applying multiaperture optical systems to conventional guided weapons by determining properties of experimental multiaperture systems.

3. Signal Processing RO 6.2.3): Demonstrate an optical implementation of the multiple invarient pattern recognition techniques developed in FY 84. Incorporate infrared light addressed spatial light modulators into the optical computer to evaluate optical processing of thermal imagery. Perform high speed correlations using computer-generated holograms as computing elements. Investigate nonlinear techniques for fabricating holograms. Explore and formulate signal processing techniques used with multiaperture sensors. Examine the possible incorporation of an optical signal processor in a conventional weapons system to utilize the imaging and pseudo-imaging information from a multiaperture sensor.

4. Propellants and Interior Ballistics (RO 6.2.4): Understand the thermochemical and photochemical decomposition mechanisms of explosives through spectroscopic techniques. Discover new low hydrogen content energetic materials by studying xenon diflouride.

5. Electromagnetic Launchers (RO 6.2.5): Experimentally, computationally, and theoretically study the basic physics of the dynamic arc plasma which constitutes the "armature" in conventional electromagnetic launcher (EML) devices. Advanced theory and diagnostic techniques will be used to characterize the nature of the interface region between the electrodes and the high conductivity plasma current flow.

6. Explosives (RO 6.2.6): Use quantum mechanics to model the underlying microscopic processes of energetic materials and then employ statistical mechanics to relate those microprocesses to the macroscopic properties of these substances. Synthesize and characterize new, high density explosives. Determine the decomposition mechanisms operative in conventional explosives. Assess the importance of chemical kinetics in predicting the explosive power, sensitivity, and stability of conventional munitions.

7. Warhead/Target Mechanics (RO 6.2.7): Understand and model the mechanics of high strain rate flow and fracture of metals and ceramics under conditions characteristic of penetration events.

8. Aerodynamics (RO 6.2.8): Derive time-accurate computational fluid dynamic techniques to predict the transonic flow field around and pressure distributions on complex multicomponent aircraft/store configurations in both the fixed and translating rigid body modes. Derive theoretical and computational techniques that predict the unsteady transonic 3-D flow field around complex multicomponent configurations undergoing arbitrary deformation.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Provide improved performance for current tactical missiles with software changes as opposed to hardware changes, thus, at minimal cost impact.

b. Provide performance capabilities required for future missile systems where classical guidance schemes will be inadequate.

c. Design improved pattern recognition prefiltering concepts for autonomous guided weapons.

d. Develop optical processing components which are suitable for use in tactical guided weapons to improve weapon performance and lower costs.

e. Provide the technology to solve high speed image processing problems postulated for advanced autonomous missile systems.

f. Utilize multiaperture optics on guided weapons systems.

g. Apply parallel processing and distributed preprocessing optical information to decrease computation time over conventional serial processing.

h. Provide high energy and thermally stable explosives.

i. Establish the technology base necessary for the realization of a repetitively firing electromagnetic launcher (EML).

j. Capability to tailor explosives and warhead materials to specific Air Force requirements and to improve the performance and safety of conventional munitions.

k. Provide strength and fracture models for the application of computational mechanics methods to conventional warhead design.

l. Provide the understanding which will lead to optimal selection of target defeat mechanisms and penetrator design.

m. Improve prediction of equilibrium and dynamic transonic aerodynamic phenomena for aircraft/store carriage configurations.

n. Provide the theoretical base for developing transonic store separation techniques and maneuvering response prediction.

SUBAREA 6.2 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 6.2 ($K)
2301A6	Weapons Physics	427.5	427.5
2301E1	Properties of the Plasma Arc in an Electromagnetic Launcher	90	90
2302E2	Penetration Mechanics Research	100	100
2303B1	Molecular Dynamics	3757	557
2303B2	Chemical Reactivity and Synthesis	2905	290
2303F3	Energetic Materials Chemistry Research	285	200
2304A1	Mathematics of Dynamics and Control	2250	100
2304E1	Optimal Control and Estimation for Tactical Missiles	465	465
2305E2	Digital and Optical Pattern Recognition Techniques	292	292
2307E1	Conventional Weapon Aerodynamics	525	525
	TOTAL		3046.5

AFOSR Focal Point: Maj Bruce L. Smith
Telephone: (202) 767-4908

TECHNICAL AREA: Weaponry

SUBAREA NUMBER AND TITLE: 6.3 Directed Energy Weapons

GENERAL OBJECTIVE: The 6.3 subarea objectives are to pursue the required research related to new concepts in directed electromagnetic weaponry including high power lasers and pulsed power beams. Areas identified for research include chemical and electrical generation, beam pointing and tracking, laser device resonators, optical components, propagation and effects on materials. Emphasis is placed on a fundamental technological level that exploits the national R&D effort to search for concepts in weapons that offer significant future advantages. New laser candidates operating in the wavelength regions below one micron must also be investigated. An FY 86 initiative will permit more detailed research in laser physics.

RESEARCH EFFORTS:

1. Lasing Mechanisms (RO 6.3.1): Experimentally determine the structure of chemically reacting shear layers. Develop diagnostics to quantitatively measure reaction rates in chemically reacting shear layers. Determine the effects of internal flow turbulence on laser beam propagation. Develop diagnostics to measure flow properties effecting laser beam propagation. Experimentally determine the effects of stimulated Brillouin scattering on high energy pulsed laser beams. Develop numerical models to assist in understanding the physical phenomena. Develop methods to enhance the production of excited N2(A) through fluid dynamic mixing.

Research is needed on the low pressure, supersonic mixing of diluted F atoms with H2/D2 and with molecules heavier than D2 such as I and DBr. Experimentally and theoretically study state-to-state chemical reaction dynamics and pumping mechanisms in flowing systems resulting in improved performance characteristics of existing laser technology. Search for new techniques to produce population inversions in specified electronic states. Better non-intrusive diagnostic techniques are also required. Develop efficient and stable computational techniques for solving stiff, nonlinear, quadratic, and partial differential equations arising in the study of chemical kinetics. Expand JANAF Thermochemical Table coverage of candidate species for lasers in the visible and short wavelength IR regions. Identify and explore new candidates for development of efficient, high-energy, electronic transition, gas phase chemical lasers. Model and experimentally verify rates and mechanisms for XeCl kinetics. Theoretically and experimentally determine the physical chemistry kinetics parameters for hot and cold XeF lasers.

Experimentally determine the physical parameters for stimulated Brillouin scattering phase conjugation of UV lasers. Experimentally determine the unknown physical parameters for Raman shifting UV frequencies to visible frequencies with excimer lasers. Study chemically pumped systems which are candidates for electronic transition laser oscillation in the visible and UV. Experimental and theoretical studies on new candidate systems will include spectroscopic and kinetic investigation. Candidate systems should efficiently produce inverted populations of electronically excited states that are metastable and show laser potential in the visible. Provide basic data

including electron scattering cross sections of rare gas atoms, metal atoms, and electronegative molecules, and heavy-body reaction rates.

Analyze laser plasma physics phenomena including discharge stability and plasma chemistry. Investigate the production of coherent short wavelength radiation from plasma media. Investigate sources of high-energy laser radiation at wavelengths below one micron, including the visible, ultraviolet, and soft X-ray region. Study relevant excitation processes including reaction rates, cross sections, rate constants and mechanisms. Calculations and measurements of distribution of vibrational, rotational and electronic energy level populations for reaction products are needed. Theoretical and experimental determination of energy exchange processes in excitation and de-excitation include cross sections rates and mechanisms. Atomic and molecular properties of reactant and product species require oscillator strengths, Franck-Condon factors, location and order of energy levels, dissociation energies, ionization potentials, and electron affinities.

Experimental research will be performed to determine reaction rates as a function of shear layer properties. Experiments will separate shear, heat release, and compressibility effects. Data will be correlated empirically for use in design of fully turbulent chemical laser nozzles. Experimentally measure the effects of flow turbulence on laser beam propagation. Evaluate feasibility of using laser doppler velocimetry for two point correlation function measurements. Determine beam quality and intensity of a reflected beam from a stimulated Brillouin scattering cell. Simulate reacting, injected flows, determine mixing phenomena and design improved mixing schemes. Calculations and experiments will address the efficient production of plasma lasing media at EUV to X-ray wavelengths. Theoretical formulations will describe the dynamics of population inversions in plasma media. Plasma screening will be characterized for charge-exchange lasers. Inner shell photoionization will be examined as a new pumping mechanism. Molecular and chemical processes pertinent to development of new electronic-transition chemical lasers will be studied. Chemical reactions which produce electronically excited species will be studied to determine reaction kinetics.

Molecular electronic states with promising spectroscopic features will be examined experimentally and theoretically to evaluate laser potential. Important items for evaluation include radiative lifetime, susceptibility to collisional quenching, potential energy curves, and production via chemical reactions. Laser fluorescence, flow tube analysis and theoretical modelling will be used to determine detailed properties of selected diatomic molecules for development into laser systems. Radiative and collisional properties including inelastic collisional cross sections are of particular interest. The interhalogen molecules, BrCl, ICl, I_2 and IF are of interest not only for visible lasers but also for shorter wavelength UV devices. Chemical excitation schemes including both direct chemical pumping and transfer from metastable molecules will be studied. Inter- and intramolecular energy disposal processes will be emphasized for hydrogen halide reactions. Rapid intramolecular energy redistribution will be studied experimentally and from an theoretical approach. The kinetics and mechanisms of the pumping reactions in the chemical oxygen-iodine laser and the proposed iodine monofluoride laser will be determined. Various methods will be used to determine the

spectroscopic manifolds of gas laser candidates including production dynamics and subsequent channels of reaction.

A substantial portion of an experimental and theoretical program in atomic and molecular physics is directed toward determining the ground and excited electronic states and transitions of molecules and also emphasizes investigations of collisional excitation and de-excitation in order to evaluate molecular states as to their potential for lasing. Model and experimentally determine XeCl kinetics rates, including sensitivity of dissociation and bottlenecking, ion-ion formation and recombination, and quenching by electrons. Develop new models and experiments to determine basic mechanisms and rates of XeF kinetics, particularly in ground states and temperature dependence. Determine limits to efficiency of narrow band extraction for applications of non-linear optics. Upgrade models to include non-Maxwellian electron distribution to bring dissociative attachment rate coefficients for F2 and NF3 to demonstrated levels. Experimentally determine the threshold and conversion rates for stimulated Brillouin scattering phase conjugation for XeF with various mediums. Experimentally determine the effect of pulse length on the threshold and conversion ratios for XeF stimulated Brillouin phase conjugation. Experimentally determine the Raman "beam print through" effects of non-uniform phase and intensity of the Raman pump.

Highly accurate numerical methods are being developed which are stable and efficient when applied to both smooth and nonsmooth stiff systems, implicit equations with constraints, and quadratic systems. Numerical algorithms that optimize computer storage, execution time, and accuracy to solve directly and iteratively large sparse linear and nonlinear systems are being developed. Also, the implementation of these algorithms and the construction of new algorithms on vector and special purpose architectures will be investigated. JANAF thermochemical tables will continue to be updated to provide thermal data of interest to future chemical lasers. Fundamental studies of the spectra and dynamics of highly excited states will be conducted toward the goal of understanding the possibilities for, and ultimately producing and controlling, XUV and X-ray sources, using harmonic generation techniques are being developed for this purpose. Core excited atoms are particularly attractive candidates for X-ray lasers, and will be studied extensively. Spectroscopic diagnostic techniques are being developed to measure, pointwise and integrated, a wide variety of combustion parameters and species at low concentrations. These will be applied to chemical and discharge lasers as needed. Pumping and excitation experiments will be used to determine kinetic rates of short wavelength candidates by probing the media with ultraviolet radiation. Small scale laser devices will be built to test, analyze and verify the performance of promising candidates. The ability of new techniques to scale to large laser performance will be studied.

2. Laser Resonator and Optical Components (RO 6.3.2): Advance the state of the art in the technology of resonators and optical coatings and films to transfer current laser research into high power laser weapons. Emphasize studies of optical coatings and surfaces since these limit the performance of components in the flux ranges of interest. This requires a fundamental understanding of the chemical and physical changes in thin layers and at

surfaces irradiated with intense light. Develop low temperature optical coating processes. Develop deformable mirror and other techniques for correction of wavefront distortion with high spatial resolution and fast response times. Evaluate laser damage threshold of optical dielectric coatings and plastic optical materials, understand damage mechanisms, and recommend changes in fabrication processes to improve laser damage threshholds. Reduce the free electron laser (FEL) concept to an efficient and effective practical device. Investigate various resonator configurations at soft X-ray wavelengths. Investigate new or greatly modified components necessary to operate high energy, short wavelength lasers effectively. Determine the basic process and life characteristics of back ion bombardment on megavolt oxide cathode diodes. Evaluate the effect of various anode (ion source) materials. Determine the effect of the ion current on the space charge of the beam. Determine the ionization cross sections of the ion species in the beam as a function of energy. Minimize surface gradient effects on megawatt bushing designs by devising grading rings and insulating sections which result in long surface paths and appropriate distributions of tangential surface gradients. Build and test a full scale bushing to verify the design. The basic technical hurdles to optical fabrication problems impacting laser weapon optical components will be investigated. Laser damage tests on dielectric and plastic optical components will be conducted to determine thresholds and damage mechanisms. This will involve direct contact with suppliers of optical materials, the evaluation of 1.06 micron, near IR, visible and UV laser damage survivability requirements for electro-optic applications such as laser designators. Theoretical and standard ultra-high vacuum approaches will be used to model and observe the chemical and physical characteristics of laser irradiated surfaces and thin films and to understand thin film formation mechanisms and characterization. Optics and spectroscopic techniques will be studied for possible low energy (0.1-10 KeV) X-ray applications. Storage ring free electron lasers will be extensively studied. Electromagnetic wiggler free electron lasers will be studied. Oscillator studies of variable wiggler free electon lasers will be continued, especially start-up conditions. Optics issues in free electron lasers will be addressed. Nonlinear phase conjugation studies, especially self-contained phase conjugate resonator studies will continue. Photochemical deposition techniques, laser evaporation and laser CVD will be studied as means to produce optical coatings for high energy lasers.

3. Laser Beam Propagation (RO 6.3.3): Determine the relationship betweeen the structure of turbulent and transitional shear layers and the optical degradation of laser beams passing through them. The effects of density ratio and Mach number on the optical performance of shear layers will be determined in a combined experimental and analytical program.

4. Laser Beam Material Interaction (RO 6.3.3): Develop experimental data and theoretical models for plasma formation by laser bombardment of various solid target materials. Experiments will be performed to study plasma formation due to laser bombardment of carbon, copper, aluminum and selenium. Develop improved understanding of the interaction of a high-power pulsed laser with various solid materials at any angle of incidence and any atmospheric pressure.

5. Ion Sources (RO 6.3.6): Develop a fundamental understanding of negative ion formation and noise generation in sources as these relate to exoatmospheric applications. Theoretical and experimental efforts in negative ion beam sources, especially those heavier than hydrogen, will grow. Neutralization schemes for negative ion beams will receive increased attention.

6. Accelerators (RO 6.3.7): Examine the physics and technology of producing high current, high quality beams in a variety of accelerator concepts. For producing and accelerating beams suitable for use in neutral beam applications, more conventional linear accelerator physics concepts need to be explored, e.g. concepts for producing higher gradient shorter accelerators with higher current capabilities. Examine new concepts for acceleration mechanisms for intense, relativistic electron beams. Develop conventional and novel high risk approaches for reducing the size and weight of accelerators. Develop novel concept for high energy, low-emittance ion acceleration for possible use in exoatmospheric applications. A study will be made on the possible use of radio frequency quadrupoles in a parallel or multiple configuration. Research will be performed using a small, experimental facility based upon a high current, space-charge dominated electron beam accelerator. Studies on conventional proton linacs will be explored. Examine rf sparking limits experimentally and theoretically to re-establish the fundamentals of high voltage breakdown in light ion linear accelerators. Examine magnetic and electrostatic beam optics control theory and concepts for adaptive optics.

7. Particle Beam Propagation (RO 6.3.8): Examine the physics associated with propagating high kinetic energy, high current electron beams in low pressure gases. Also examine the propagation of neutral beams in the upper atmosphere or near space. Examine the physics of endoatmospheric propagation of multiple pulses in ion density channels. Validate models for exoatmospheric propagation of plasmoids. Theoretically and experimentally evaluate the fundamental plasma physics issues associated with forming, accelerating, launching, and transporting plasma projectiles (hydrodynamic plasma jets and plasmoids with imbedded currents and self-supporting magnetic fields) at very high velocities (1000 milometers/sec) for high altitude and space weapons applications. Single pulse stability phenomena will be studied, including beam nose erosion, two-stream instability, hose instability, and channel behavior. The preparation of an intense relativistic electron beam for propagation is of paramount importance. Rise-time control, current density enhancement and tailoring the emittance of a beam pulse will receive the major emphasis. Electron beam endoatmospheric work will be largely replaced by an expanded effort in positive ion and neutral plasmoid exoatmospheric propagation. Studies will be made on promising plasma ensemble formation schemes including production of a high density jet from a high energy density plasma pinch, the production and acceleration of a compact plasma torus, and very high speed modest density plasma produced by any of a variety of plasma guns.

8. Pointing and Tracking (RO 6.3.9): Examine the observables of intense beams, both electron and high energy atomic beams. The beam sensing of high energy atomic or neutral beams is critical to the problems of neutral beam steering, pointing and accelerator control. Examine charged particle-plasma interactions. Experiments to diagnose beam observables will be performed.

Both laser resonant backscatter (LRBS) and pinhole techniques will be explored. A LRBS concept will be designed to measure the fluorescence of backscatter in one plane as a function of angle. For pinhole studies an in-house effort using IPA support is contemplated.

9. Beam-Material Interaction (RO 6.3.10): Examine the physics of intense beams interacting with materials, e.g. plastics, plasmas, and electronic materials. The interaction of intense beams with matter involve a new class of physics problems associated with collective and many-body behavior quite unique from the single-particle, classical approach. Develop experimental data and theoretical models for plasma formation and radiation emission due to particle beam bombardment of various solid target materials. Intense beams will be injected into high density gases, plasmas and electronics and their interactions examined. Several materials will be irradiated for target feedback signatures. High energy particle transport codes will predict products of collisions between beam particles and target atoms and project the quantity of gamma rays and neutrons expected. Experimental and theoretical studies of damage plasma formation and radiation emission caused by intense electron beam bombardment of crystal and other solid materials will be performed.

10. Power-Generation (RO 6.3.11): Improve electrical energy generating, switching, and storage systems to operate accelerators. Research will be conducted in electron-beam triggered switching, optical spectroscopy of switch plasmas, opening switches, inductive storage and insulation breakdown and alternatives for space-based prime power generation.

11. Power Conditioning (RO 6.3.12): Analyze electron beam controlled switches, including discharge stability and plasma chemistry. Provide basic data such as ionization attachment and recombination rates for insulating type gases and gas mixtures for electron beam controlled switches. Develop new closing switch concepts with accurately timed, low-jitter, improved repetition rate, voltage, and current capabilities. Concepts for both low-and high-repetition rate opening switches are essential. Identify, evaluate and test power conditioning techniques employing explosive pulse power, inductive storage, and opening switches suitable for delivering megajoule submicrosecond energy pulses to a plasma/accelerator load which can be packaged for use in space. A closed cycle device including DC electrodes and an electron gun permits the separation of ionization effects and mobility effects in high pressure discharges. This provides a highly controlled plasma for investigating energy relaxing processes in electric discharge lasers and electron-beam controlled switches. Products of plasma chemistry are detected on line with tunable diode laser absorption, mass spectrometry, and off-line with infrared Fourier transform spectroscopy of gas samples. Measurements are being made, at high electron energy resolution, of lineshapes for attachment of thermal electrons to perfluorinated carbon compounds, HCl, LiH, and other Li- and H-bearing salts. The electron attachment process is important in extinguishing arcs in opening switches.

12. Microwave and Millimeter Wave Weapons (RO 6.3.13): Perform research to realize high power microwave and millimeter radiation sources capable of the destruction of systems by Joule heating and breakdown through induced voltages in critical systems components. Perform research to identify new concepts for

sources of high power microwave and millimeter wave radiation. Free electron laser concepts will be applied to the millimeter wave region. High available gains will be combined with improved depressed collector techniques to produce efficient devices. New device concepts which combine the high gain transverse bunching of gyrotrons with the Doppler upshift of FEL's will be studied.

Theoretical and experimental research on the production of high-power millimeter and microwaves by collective non-neutral plasma phenomena such as that found in electron cyclotron masers (gyrotrons), electron beam/plasma interactions, klystrons, and coupled-cavity traveling wave tubes will be fostered.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Develop computer codes that will accurately predict the operating performance of lasers.

b. Increase the stability and performance of electric discharges.

c. Increase the efficiency and performance of existing laser systems.

d. Evaluate the potential of new high power laser concepts.

e. Develop new, efficient high power lasers operating at shorter wavelengths.

f. Improve the mixing and flow characteristics of laser flow dynamics.

g. Develop new laser resonator devices which can correct for medium inhomogeneities and mirror distortions.

h. Develop new laser mirrors and window materials by depositing selected well-controlled coatings on the support material.

i. Improve propagation capabilities to deposit energy on target.

j. Predict results of intense laser interactions with materials.

k. Demonstrate the feasibility of charged particle beam propagation.

l. Develop new energy storage devices for pulsed power application.

m. Evaluate the potential of new microwave and millimeter wave weapons.

n. Demonstrate the feasibility of using plasmas as high power, high repetition on/off switches for directed energy devices.

o. Develop electron beam technology for laser communications and laser weapons, intense microwave sources, and plasma jets.

SUBAREA 6.3 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 6.3 ($K)
2301A1	Optical Physics	5222	2595
2301A4	Atomic and Molecular Physics	1525	770
2301A7	Space Power and Particle Beams	3900	2400
2301B2	Special Topics in Physics	744.5	744.5
2301A8	Plasma Physics	3116	1609
2301F1	Guidance, Control and Laser Research	385	237
2301S2	Plasma Reseach, Gas Discharges and Laser Plasmas	1240	270.5
2301Y1	Particle Beam Research	515	515
2301Y2	Pulsed Power Technology	391	391
2303A2	Surface Chemistry	1963	858
2303B1	Molecular Dynamics	3757	1287
2303Y1	Laser Kinetics	540	540
2303Y2	Electronic Transition Chemical Laser Concepts	620	620
2304A3	Mathematics of Computation	3000	125
2307A4	Internal Fluid Dynamics	2400	90
2308A1	Rocket Combustion Dynamics	3173	30
2308Y1	Laser Fluid Mechanics	440	440
	TOTAL		13522

AFOSR Focal Point: Lt Col Lawrence D Hokanson
Telephone: (202) 767-4935

TECHNICAL AREA: Weaponry

SUBAREA NUMBER AND TITLE: 6.4 Civil Engineering Technology

GENERAL OBJECTIVE: The objective of this research is to better understand the engineering properties and behavior of civil engineering materials and structures. It supports development of new materials or new approaches that will lead to the survivability of strategic and tactical structures in a nuclear weapons environment, survivability of strategic and tactical structures in a conventional weapons environment, rapid repair of tactical and logistical aircraft launch and recovery surfaces during conventional warfare, and unique requirements for maintaining Air Force facilities worldwide. Tasks are in soil mechanics, structural dynamics and materials, and soil-structure load transfer. Research areas include developing constitutive models for geotechnical and construction materials, studying the strength and fracture characteristics of brittle materials, investigating explosion-induced soil liquefaction, developing structural response models, and identifying and measuring in situ soil properties.

RESEARCH EFFORTS

1. Constitutive Models (RO 6.4.1): Mathematically model both the static and dynamic stress-strain relations of soils subjected to a variety of three dimensional loadings. Determine the effects of strain rate and deformation-induced anisotropy on the constitutive behavior of fine grain soils. Identify chemical and physical mechanisms that govern the constitutive behavior. Define the stochastic, spatial and temporal variations in soil materials and processes which influence the constitutive relationships.

2. In Situ Soil Behavior (RO 6.4.1): Identify and measure soil properties representative of the material's response to a variety of environmental conditions, including temperature and moisture changes, pore pressures, geological formation and imposed loadings. Devise improved laboratory techniques for simulating field boundary conditions. Define the relevant soil fabric micrometrics.

3. Soil Stabilization (RO 6.4.1): Characterize the strength and fracture properties of stabilized soil layers. Model aircraft gear/soil interaction problems to include stress dependent soil parameters and edge effects. Examine effects of stabilization techniques on soil fabric micrometric.

4. Liquefaction (RO 6.4.1): Mathematically model the process of blast-induced liquefaction; identify and define soil parameters, flow characteristics, site conditions and loading factors which govern its occurrence. Model the effects of p-wave s-wave interaction on liquefaction.

5. Transient Soil Properties (RO 6.4.1, 6.4.5): Define the process of soil moisture, density and conductivity fluctuation and effects on soil performance properties.

6. Rock Mechanics (RO 6.4.2, 6.4.4): Mathematically model the constitutive behavior of continuous and discontinuous rock masses. Model the behavior of joints within geomaterials. Determine the micromechanics of failure and flow of rock masses.

7. Structural Response (RO 6.4.3): Mathematically model the response of hardened structures to high stress impulsive loads and relate material failure to structural failure. Define dynamic loading functions and damage mechanisms. Examine the influence of structural details, external load parameters, and their concomitant physical uncertainty on the nature of failure in structural members under impulsive disturbances.

8. Fracture Characteristics of Brittle Materials (RO 6.4.2): Define the process of brittle materials resistance to fracture caused by airblast, thermal and shock loads. Determine and model physical or chemical processes occurring in the process zone and relate to strain rate effects.

9. Concrete Stress-Strain Modeling (RO 6.4.2): Establish constitutive models for plain and reinforced concrete subjected to dynamic multi-axial stresses. Model the steel/concrete interaction zone and quantify stress transfer for a range of aggregate and matrix types. Determine mechanics of aggregate controlled concrete and the chemical/physical basis of constitutive relations and strain rate effects.

10. Expedient Facilities (RO 6.4.2): Define the mechanics of facilities other than hardened, reinforced concrete structures. Mathematically model the dynamic buckling of structural members for lightweight, reticulated structures.

11. Structure-Media Interaction (RO 6.4.4): Develop an understanding of the effect of strain localization on the softer of two materials forming an interface boundary.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Improve site selection and soils evaluation techniques for construction of major Air Force systems.

b. Support the ground shock studies of AFWL and DNA through the development of soil models and instrumentation.

c. Enhance the survivability of Air Force systems to ground motions resulting from earthquake and blast loading.

d. Improve materials and design criteria for unsurfaced or minimally surfaced runways.

e. Improve the design of protective structures by developing rational mathematical models for construction materials.

f. Develop high-strength materials for use in construction of Air Force systems designed to withstand multiple nearby nuclear and non-nuclear detonations.

g. Develop new lightweight structures for aircraft and personnel shelters capable of withstanding impulsive loads.

h. Support development of alternate launch/recovery surfaces for immediate aircraft operations after attack by non-nuclear weapons.

i. Develop new high-strength, rapidly-placed materials for repair of bomb damaged runways and taxiways.

SUBAREA 6.4 FY 86 PLANNED FUNDING:

TASK NR		TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 6.4 ($K)
2302C1	Soil Mechanics	1450	1450
2302C2	Structural Dynamics and Materials	1250	1250
2302Y2	Soil Structure Load Transfer	235	235
	TOTAL		2935

AFOSR Focal Point: Dr A.J. Matuszko
Telephone: (202) 767-4963

TECHNICAL AREA: Weaponry

SUBAREA NUMBER AND TITLE: 6.5 Environmental Aspects of Weapon Systems

GENERAL OBJECTIVE: Air Force Weapon Systems and Operations must be designed and operated to minimize adverse Environmental Quality degradation during peacetime. To maintain readiness and mission effectiveness while complying with national environmental legislation, it is necessary to establish a sound scientific basis for evaluating environmental effects of future weapon systems and AF-unique operations. This will allow AF managers to evaluate alternatives early in the weapon system concept phase avoiding unnecessary delays in acquisition or deployment. Research is required to investigate the factors responsible for generation of pollutants in aircraft and missile engines and maintenance and repair operation. Work is needed to better understand the chemical and physical mechanisms controlling transport of pollutants through natural ecosystems, chemical and engineering processes for controlling the generation and/or release of AF-unique pollutants. Improvements are needed in optical and electrochemical instrumentation systems for measurement and identification of pollutants and their degradation products in effluents and ambient environments. (Subareas with related ROs: 1.4 and 5.2.)

RESEARCH EFFORTS:

1. Emissions Measurement and Pollution Monitoring (RO 6.5.1): Improve techniques for emission measurements for monitoring pollution sources and to determine air and water quality. New methods and instrumentation need to be developed which are more rapid, sensitive, reliable than existing techniques. The identification and measurement of pollutants from aircraft emissions and toxic vapors from missile accidents.

2. Environmental Chemistry (RO 6.5.2): Obtain information on equilibration of hydrocarbon mixtures with water which will be useful in controlling hydrocarbon fuel spills. Investigate the adsorpion/desorption reactions of nonionic chemicals to establish surface interactions that control the transport of these chemical species, especially in low organic carbon systems.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Develop advanced detection techniques for monitoring engine performance and exhaust emissions.

b. Provide basic information to develop predictive models of hazardous waste transport through soil systems to groundwater.

c. Provide specific data on transport of chemicals currently used by the Air Force.

d. Expand data base and help develop hazardous waste cleanup technology.

SUBAREA 6.5 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 6.5 ($K)
2303A1	Chemical Techniques	1303	110
2303B2	Chemical Reactivity and Synthesis	2905	60
2303Z1	Solvent Transport Mechanisms	40	40
	TOTAL		210

AFOSR MANAGER: Dr Horst R Wittmann
Telephone: (202) 767-4985

TECHNICAL AREA 7: Electronics

INTRODUCTION

The Air Force electronics basic research program strives to provide the fundamental basis for developing future generations of electronic devices and systems.

Electronics decisively influences most all Air Force missions such as in reconnaissance and surveillance; navigation, guidance and control; command control, communications and intelligence; components and electronic warfare. This program is concerned with the understanding of fundamental principles which govern electronic processes such as signal propagation, data processing speeds, radar ranging and resolution and radiation hardness. The understanding of these principles will enable the engineer to model and predict performance of electronic devices and systems. For this reason, research in the fields of physical electronics including ultra submicron electronics, antennas and propagation, and analog (optical, superconductive) and digital signal processing is strongly emphasized. In addition, a new research program will be started which will address interdisciplinary issues of electromagnetic propagation and signal processing in monolithic millimeter wave integrated circuits.

Electronics is a rapidly progressing field. Recognizing that the commercial electronics industry performs massive research and development, the Air Force program in electronics emphasizes research on those technologies, for which no significant commercial market is foreseen or where application of basic research funding will greatly accelerate progress in technologies important to the Air Force.

FY 86 PLANNED FUNDING:

MAJOR THRUST INITIATIVE:	FUNDING ($K)
Monolothic Millimeter Wave Integrated Circuits	1000
TOTAL	1000

SUBAREA NUMBER	TITLE	FUNDS SPTG SUBAREA ($K)
7.1	Reconnaissance and Surveillance	2966.2
7.2	Navigation, Guidance and Control	1744
7.3	Command, Control, Communications and Intelligence	5695
7.4	Components	16727.3
7.5	Electronic Warfare	1070
	TOTAL	28202.5
	TECHNICAL AREA TOTAL	29202.5

AFOSR Focal Point: Dr. Gerald Witt
Telephone: (202) 767-4931

TECHNICAL AREA: Electronics

MAJOR THRUST INITIATIVE: Monolithic Millimeter Wave Integrated Circuits

GENERAL OBJECTIVE: Hybrid microwave and millimeter wave integrated circuits (MIC, MMIC) fabricated from compound semiconductor materials have had considerable impact on airborne systems over the past few years. This technology has been applied to a variety of avionics components and has resulted in an increased functional capability as well as a reduction in cost. A principal impediment to the further application of such circuits is the relatively large amount of highly skilled manual labor involved in hybrid circuit assembly, interconnection and adjustment. Among the other factors at play are the state of compound semiconductor (GaAs, InP) material technology, the lack of adequate design rules for devices and circuits, and the perfection of suitable processing. This initiative seeks to identify materials improvements, device designs and automatable processing techniques supporting the development of monolithic MICs and MMICs (MMICs and MMMICs). Monolithic refers here to the fabrication on a single semiconductor chip of all needed active and passive components such as transistors, capacitors, inductors and interconnections. (In hybrid circuits, two or more devices or chips must be interconnected). Among the significant advantages of the monolithic approach are: cost reduction, reliability, improvement, size and weight reduction, performance improvement, and new improved functions.

RESEARCH EFFORTS:

Basic research is needed in several areas to support the emergence of this technology. This includes work on substrates, active layers, device modeling, millimeter wave device designs and monolithic integration. The broad range of potential Air Force applications in this area dictates the simultaneous pursuit of programs in both GaAs and InP materials technology. Close coordination with existing and planned Army, Navy and DARPA programs in this area are mandatory to optimize the initiative investment.

FY 86 PLANNED FUNDING: $1,000K

AFOSR Focal Point: Lt Col Robert W Carter Jr
Telephone: (202) 767-4931

TECHNICAL AREA: Electronics

SUBAREA NUMBER AND TITLE: 7.1 Reconnaissance and Surveillance

GENERAL OBJECTIVE: Reconnaissance and surveillance are primarily concerned with searching, mapping, and monitoring both wide regions and specific targets above and on the earth's surface to produce strategic intelligence and attack alarm. Objects, weather conditions, and battle damage must be detected, identified, located and evaluated. These functions are carried out mainly by exploitation of electromagnetic techniques in spectral regions ranging from microwave through ultraviolet frequencies (without ignoring other techniques such as acoustic and seismic). Research emphasizes investigations in sensor science and technology with regard to novel approaches, resolving power, sensitivity, signal-to-noise ratio, and cost effectiveness and includes advances in data processing and pattern recognition. (Subareas with related ROs: 2.3, 3.1, 3.2, 7.3, 7.4, 7.5).

RESEARCH EFFORTS:

1. Target Detection and Identification (RO 7.1.1): Research will explore two-dimensional real-time optical matched filtering using optical sources other than purely coherent ones. The major configuration to be studied is the matched-filter correlator which will be analyzed with respect to wavelength dependence, required degree of spatial coherence, effect of object displacement or rotation, feasibiltity for multiplexing the filter, and use of broad-band holographic elements. Investigation will include computational and experimental techniques for recognizing and tracking of moving objects in a sequence of real scenes. Research will examine the potential of applying Rate Distortion Theory to the image understanding problem and obtaining a rate distortion surface for a time varying image signal class. Another aim is to develop analytical and numerical techniques for predicting electromagnetic scattering characteristics of conducting and lossy dielectric targets in the frequency range from UHF to C-band. A data base will be acquired for bistatic scattering from low radar cross section (RCS) targets, specifically those covered with radar absorbing materials (RAM). Other efforts will look at artificial intelligence techniques for performing automatic pattern recognition. Automated techniques will be developed to discriminate between different targets and interfering clutter in a high false alarm rate environment. This effort will evaluate techniques utilizing LISP encoded rules for extracting a more extensive set of targets from additional imagery sources. These methods of analysis shall also include statistics and preliminary decision nodes which will avoid any unnecessary steps in the overall classification process.

2. Propagation and Scattering (RO 7.1.2):

Research will develop techniques for predicting electromagnetic scattering characteristics of conducting and lossy dielectric targets from UHF to C-band, and acquire a data base for bistatic scattering from low radar cross section targets, especially those covered with radar absorbing materials. Terrain-scatter relationships will be studied to construct more accurate models of scattering from rough surfaces. Scattering models will be developed for better determination of multipath and clutter effects which cause degradation of target detection of low flying, low cross section targets, errors in position information obtained from surveillance radars, and degradation in performance of low sidelobe antennas. Using stochastic modelling, the peformance limitations of Doppler, and other correlative processors affected by phase frequency instabilities will be evaluated.

3. Sensors and Sources (RO 7.1.3): Efforts will formulate optimum procedures and algorithms for multiple hypothesis testing of multiple sensors remotely located in a distributed environment. The basic concepts dealing with detection, estimation and decision theory will be investigated for a set of multiple channels characterized by a vector waveform. The work will take into consideration the effects of system parameters and corresponding limitations.

4. Radars and Antennas (RO 7.1.4): Research will strive to establish the fundamental principles underlying the design and construction of low-profile microstrip antenna elements and arrays that conform to the surface of the supporting vehicle. The quality of radar surveillance will be enhanced by increasing the computational throughput, and will decrease the cost, size, and weight of the radar systems through process integrations. Arrays of groove and H-guide leaky wave antenna elements will be studied for wide-angle scan capability in the millimeter wave region. Diode-switched spiraphase printed circuit elements will be examined as array elements for millimeter wave scanning antennas, as will the use of generally anisotropic materials for substrates and dielectric covers for polarization and scan-angle control in micro-strip antennas. Efforts will also be directed for the inherent parallel nature of optical processing, this emerging technology will be investigated with regard to the preprocessing of the data from large antenna arrays. More specifically, studies will be conducted into the application of optics, asousto-optics, and electro-optics towards realizing massively parallel processing using systolic arrays and tree structures. Special emphasis will be placed on integrated acousto-optic implementations. In addition, research will focus on nonlinear optical processes in semiconductor and other crystalline materials. Of particular interest will be nonlinear optical phase conjugation processess capable of realizing the real time information processing of electromagnetic fields. The all optical nonlinear mixing techniques avoid the currently employed electronic feedback networks and result not only in greater time-bandwidth products but also in lower cost, size, weight and reduced system complexity.

APPLICATIONS TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Radar systems for all-weather detection and tracking of slow moving low cross-section targets concealed by foliage or imbedded in a severe clutter environment.

b. An all-weather day-night capability for noncooperative long range target classification and identification with reduced data processing requirements.

c. More efficient, lower cost antennas with improved performance for over the horizon radar applications without sacrificing critical design parameters (such as detectability).

d. Cost-effective antennas for high performance aircraft and missiles, resulting in: minimal aerodynamic drag, reduced additional fuel requirement, minimized effect on overall vehicle performance, low weight and small size for given antenna gain, lower susceptibility to jamming and wider bandwidth for frequency hopping.

e. Technologies for diffraction limited imaging of space-borne objects.

f. Technologies for target detection and identification from less than ideal information.

g. Improved technology for multi-sensor radar systems.

h. Enhanced radar range, resolution, and improved surveillance capabilities.

i. Baseline technology for automatic target detection and identification.

j. Better clutter and multipath models for signal processing in target detection.

k. Improved detectability, tracking, and identification of low observable, low flying targets.

SUBAREA 7.1 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TOTAL FUNDS SPTG SUBAREA 7.1 ($K)
2305A9	Joint Services Electronics Program	2750	250
2305B3	Digital Information Electronics	641	250
2305B4	Optical Signal Processing	1778	950
2305J3	Electromagnetic Radiators	744	227
2305J4	Electromagnetic Scattering	754	754
2305J8	Signal Processing	600	168
2311G3	Solar Research	1912	367.2
	TOTAL		2966.2

AFOSR Focal Point: Lt Col Robert W. Carter Jr
Telephone: (202) 767-4931

TECHNICAL AREA: Electronics

SUBAREA NUMBER AND TITLE: 7.2 Navigation, Guidance and Control

GENERAL OBJECTIVE:

Technology has advanced sufficiently to permit multiple use of inertial navigation systems. Guidance, the process of using vehicle position, velocity, attitude, and mission data to compute thrust and steering commands, falls between navigation and control and includes Space, Inter-Continental Ballistic Missile, Anti-Ballistic Missile, Air-to-Air, and Air-to-Surface Missile applications. Control, the process of causing a dynamic system to behave in a desired manner, as used here, includes spacecraft attitude control but specifically excludes aircraft flight control (SEE TECHNICAL AREA 4.3). Desired requirements for future Air Force operations are: Weapon terminal guidance techniques compatible with moving target indicating radars and forward looking infrared systems, self-contained integrated flight and fire control systems for air superiority fighters, and integrated reference and flight control systems to provide more accurate weapon delivery and greater aircraft performance options. Redundant strapped down inertial systems with radio navigation integrated with flight controls can substantially improve control capability. Bistatic radar techniques are postulated for penetrating tactical aircraft to enable covert ingress and egress from the target area. Strategic offense requires accurate and autonomous navigation systems which operate reliably in severe defense threat environments. To support this technology, improved strapped down sensors and radio receivers that can operate accurately in a high jamming environment are necessary.

RESEARCH EFFORTS:

1. Advanced Gyroscopic and Inertial Sensors (RO 7.2.1): Research will pursue new alternatives to rotational rate sensing which avoid the intrinsic difficulties in present laser gyroscopes and can lead to essential improvements in cost and applicability. Low cost, all solid state, guidance components to meet modest accuracy requirements of tactical missiles will be investigated, as well as, new techniques and concepts which would allow these components to perform at very high accuracies. A digital control loop will be designed and the 0.62 M^2 passive resonant ring laser gyro will be recalibrated. Development efforts will be directed towards production techniques and processes for low scatter laser gyro mirrors.

2. Advanced Signal Processing Techniques and Large-Scale Integrated Circuits (RO 7.2.3): Research will be directed towards development of a superconducting hybrid analog/digital signal processing technology to provide ultra-wide bandwidth, large time-bandwidth products, and efficient real time signal processing to meet future communication/navigation/identification requirements. Solutions should drive towards high antijam margins, low probability of intercept, large signal/noise enhancement, and efficient computation operations. Superconducting technology will be used to develop yields of programmable analog signal processors/preprocessors with a capability to process ultra-wide bandwidths and large time-bandwidth product waveforms and to route pre-processed signals to digital systems. Components will be integrated via high quality microstrip links on low-loss substrates to develop superconductive convolvers and time integrating correlators with 2-20 GHz bandwidths and 10^3 to 10^6 time-bandwidth products. Components for input/output, tapping, multiplication, and summation will be developed with geometries and processes compatible with microstrip delay lines. Technology to meet requirements for input/output (bandwidth and dynamic range), delay/shift (low loss, low dispersion, high transfer efficiency), tap/weight (accurate coupling, low reflection, phase coherence, intertap isolation, precise fixed or programmable tap strength), mixing (efficient, wide dynamic range, bilinear multipliers), summation (coherent spatial summation with hybrids), and integration (time integration with high Q) will be developed. Techniques will be sought for taking advantage of the accuracy of digital systems and both the speed and power of analog systems.

3. Integrated Systems Data Processing (RO 7.2.8): - Efforts will develop integrated approaches and alternatives for real time, optimal data processing related to the identification of control dynamics, signals and decision making beyond present speed. Work will also focus on development of improved and computationally attractive methods for the analysis and design of multivariable large scale systems and optimum controllers. Transfer properties of multiple-input, multiple-output feedback systems will be analyzed when nonlinear subsystems are interconnected. A novel, practical design procedure for multivariable linear control based on frequency domain methods will be investigated. Study also will look at the problem of numerical methods and sensitivity procedures for determining high order optimal control policies for large scale systems on moderate size computers. Corresponding mathematical methods and computational algorithms to optimize, and control such devices and systems will be formulated. The problems associated with differences between input and reference imagery in missile guidance will be examined. To do this, the following three projects will be pursued: (1) development of architectures and algorithms for pattern recognition using multi-sensor data with geometrical distortions, (2) analysis of techniques for pattern recognition using laser diodes and holographic optical elements, and (3) study of the necessary digital support hardware and software for data recording and simulation of optical processors. Dynamic systems will be studied and the structural properties of a system will be related to their ease of identification from noisy observations. Development of improved system identification techniques will be addressed.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Removes present limitation on the use of a nuclear magnetic resonance gyroscope in a strapped-down mode.

b. Optimizes laser gyroscope performance for applications ranging from small, low accuracy, integrated optics devices for tactical weapons, to extremely large devices for geophysical research.

c. Develops real-time correlators for missile guidance.

d. Improves laser gyroscope navigation accuracy, life, and cost.

e. Develops new motion and stress sensors.

f. Develops new methods for simplified analysis and synthesis of navigation, guidance and control systems.

g. Finds ways to control highly maneuverable vehicles with distributed systems.

h. Provides better understanding of laser gyro operation as function of mirror quality.

i. Provides improved lase gyro operation by improving mirror quality

j. Develops the basis for improved optics for DoD optical and electro-optic systems.

SUBAREA 7.2 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 7.2 ($K)
2305A8	JSEP Information Electronics	715	230
2305B1	Optical and Acoustical Processing	2292	182
2305B2	Advanced Sensors	715	715
2305R3	Inertial Navigation Components	467	467
2305R5	New Spatial Light Modulator	150	150
TOTAL			1744

AFOSR Focal Point: Dr Gerald L. Witt
Telephone: (202) 767-4931

TECHNICAL AREA: Electronics

SUBAREA NUMBER AND TITLE: 7.3 Command, Control, Communications, and Intelligence

GENERAL OBJECTIVE: Command, Control, Communications, and Intelligence (C^3I) embodies the facilities, equipment, communications, information gathering procedures, and personnel essential to a commander for planning, directing, and controlling operations of assigned forces pursuant to the missions assigned. C^3I in all of its forms is so complex and diversified, encompassing so many technical areas, that it takes multi-volume reports to describe all of its ramifications. Therefore, a basic research program in C^3I should be directed only toward that problem area deemed to be the most critical. At the present time, this area is best described as the technology base required to provide the tactical commander with the latest, best data in the clearest possible form and at his greatest convenience. In more specific terminology, this encompasses the need for adaptive, survivable communications, distributed data processing and data bases, rapid intelligence exploitation, novel transmission channels to extend the security and flexibility of communications, parallel optical processing techniques, automation, and artificial intelligence.

RESEARCH EFFORTS:

1. Signal Detection and Processing (RQ 7.3.1): Multivariable digital filters will be investigated and research will continue on fundamental mathematical aspects of communication and information theory. Methods will be investigated for compensating for effects which degrade the accuracy of remotely sensed datas by mathematically inverting some of the degrading phenomena. Work is underway to develop an analytical framework for inverting the effects of multidimensionsal degradations, linear or nonlinear, under the presence of noise so that ultimately it will be feasible to implement the developed algorithms with reduced computational complexity and, where necessary or feasible, in real time. Efforts are underway to study the constraints and potential of optical components for data processing and computation by analog optical Fourier transformations, as well as a study of optimal digital encoding of jump and continuous images. Work will focus on synthesizing classes of general non-monotonic, nonlinear, multi-dimensional functions in optimal signal processing systems. Digital filters with higher speed and accuracy, smaller size and weight will be investigated. Large digital systems of interconnected models will be addressed. VLSI circuits will be specified. Several wideband multichannel acoustoopic and magnetooptic devices/concepts will be investigated with regard to three application areas: very high scanning-rate light beam deflection switching, spectrum analysis of very wideband RF signals, and high speed acoustooptic readout for integrated optic signal processing. Basic device configurations will be used to study the underlying interaction mechanisms, to establish the key design parameters/criteria, to determine the ultimate capability of the devices, and to explore unique applications. A variety of components will be integrated

via high quality microstrip links on low-loss substrates to develop superconducting convolvers and time-integrating correlators. The second phase of this continuing program will incorporate the requisite discrete components into a superconducting convolver with a bandwidth of 2 GHz and a time-bandwidth product of at least 200. A superconducting time-integrating correlator concept will be developed into a practical design and a device with up to 64 individual time (or frequency) bins will be demonstrated. Infrared spectroscopy and anelastic loss techniques will be employed to determine impurity type and concentration in quartz crystals to reduce undesirable frequency shifts caused by aging. The general objective here is to develop advanced time and frequency generation systems. The feasibility of acusto-optic modulation methods for state inversion in optically pumped, cesium-based frequency standards will be examined. Improved elastic coefficients for quartz material will be derived to permit increased accuracy in resonator design.

2. Propagation Media (RO 7.3.2): Research will be conducted to assess the ability of generating long electromagnetic waves (ELF/VLF/LF) through the interaction of charged particle beams with the atmosphere. A theoretical and experimental investigation will be carried out on strong non-linear interactions between intense high-frequency electromagnetic waves and the ionosphere. A high current, high energy modulated electron beam source for beam-wave generation will be sought. Techniques will be developed for data analysis and interpretation of data to be acquired in beam-wave generation experiments. The nonlinear interaction of high powered HF radio transmitters with the ionospheric plasma will be explored, looking for possible self-limiting perturbations or interference with the operation of other systems. The electromagnetic properties of open dielectric waveguiding structures having cross sections of the order of a wavelength will be calculated in uniform, periodically modulated, or nonuniform materials. New techniques providing convergent representations for wave effects will be applied to open, multi-moded regions with very large cross sections.

3. Imagery and Holography (RO 7.3.3): A new type of holographic optical element, called a partitioned computer generated hologram, will be investigated. Numerous approaches to the design of the hologram will be sought which will provide large numerical range, high accuracy, and good optical efficiency for optical computing. Partitioning algorithms will then be formulated capable of producing these partitioned computer generated holograms by electron-beam lithography. Techniques for performing optical information processing and holography with incoherent light in such a manner that the resulting system will obey the laws of coherent optics will be devised. The fundamental merits and basic limitations of these incoherent techniques will be analyzed and a system transfer function will be formulated for the promising techniques. Two different approaches to nonlinear optical processing will be pursued: direct use of light modulator nonlinear characteristics, and conversion of input intensities to spatial frequencies by employing the variable grating mode of liquid crystals. The first approach will devise techniques for nonlinear processing which can take advantage of the nonlinear transmittance characteristic of spatial light modulators which employ electro-optically controlled birefringence. In the second approach a generalized model of nonlinear optical processing with a variable grating mode (VGM) liquid crystal light valve will be formulated, and theoretical models of

the physical origin of the VGM effect will be established and tested against known experimental data. A logic system based on the VGM effect will be investigated. Theoretical studies of the basic mechanism of the VGM effect will be pursued with a molecular model of the effect consistent with all the known physical and chemical facts being constructed. Polarization diffraction studies will be conducted to help determine the model, and free energy calculations for the model will be made. The model will be used to suggest improvements in the practical realization and optimization of the effect. Research will attempt to demonstrate that a mathematical concept which has been used in conjunction with medical computed tomography can be performed rapidly and accurately by existing 1D devices. A Radon transform will be performed on the input to reduce the dimensionality of the input data by integrating over a set of lines in the 2D case or planes in the 3D case. Convolutions or filtering operations will then be performed on the 1D signals and the inverse Radon transform performed in order to reconstruct the desired 2D or 3D output. The major challenge exists in implementing these operations at speeds at least equivalent to TV scan rates. Research will investigate various processor architectures which employ a special arrangement of 1D acousto-optic light modulators to process 2D signals several orders of magnitude faster than current optical processors using 2D light modulators. Various processor architectures will be considered which employ, in some fashion, a combination of time integration and space integration. The factors affecting performance of these various architectures will be investigated in terms of the processing power, accuracy, and realizable signal processing operations. The feasibility of such 2D acousto-optic processing will be demonstrated with an experimental processor. Investigations will be conducted into the capabilities of these processors to handle complex signals by such techniques as multi-spectral processing.

4. Electronic Encoding/Decoding (RO 7.3.4): Research will be undertaken to demonstrate that an Interpolated Differential Pulse Code Modulation (IDPCM) process can be implemented by optical means. The feasibility of an adaptive IDPCM compression scheme will be considered. Various techniques of implementing a hybrid optical-digital video bandwidth compression system including optical Fourier transforming, holography, Schlieren optics, and optical Hadamard transforming will be investigated. A number of design approaches based on the replacement of actual random processes with another that is close statistically but earier to encode and decode will be analyzed. New techniques will be sought giving better performance and easier implementation in rate distortion theory for data compression.

5. Computer Software/Hardware (RO 7.3.5): Various methods for software design will be explored to find a language which allows early incorporation of specification changes to minimize modular connectivity and to express control and data flow clearly. Software models will be developed. Testing and verification will be examined at a high level of abstraction. Efforts will be made to develop a number of languages for representations at the various design levels (architecture, logical design, simulation of performance, component layout and mask specification). The languages sought must provide a clean semantic basis for interactive manipulation within each level, as well as transformations between levels in a way that will permit the verification and preservation of the design intent. The final design will be examined in the context of a specific design to be chosen from several available algorithms in speech processing and pattern recognition.

6. Distributed Computer Architecture (RO 7.3.6): Work will continue in basic studies in distributed control and team decision making for use in C^3 theory. Congestion-control and routing algorithms will be extensively investigated. Design of easily maintainable and fault tolerant digital systems and the problems of diagnosis of large digital systems of interconnected modules will be investigated. Techniques will be investigated to minimize data sharing of distributed systems while parallelism is maximized.

7. Secure Aerospace Communications (RO 7.3.8): Research will address the problem of tracking a spread spectrum signal once acquisition has occured. A Spread Spectrum System Simulator will be used to study acquisition and tracking strategies for spread spectrum signals in benign and fading environments under differing modulations, spreading techniques, channels, and interferers. Various modulation and encoding schemes will be comparatively evaluated to determine the data rates that can be supported over mobile radio channels in very hostile propagation enviroments. The use of spread spectrum systems will be investigated and compared to conventional systems. Circuits will be developed using the RADC/DARPA foundry facilities to obtain designs and experimental models for advanced processor architectures. The emphasis will be on algorithms and architectures providing high speed adaptive signal processing capabilities when integrated with advanced VLSI circuit technologies. A systolic algorithm and architecture simulator will be written in a high level computer language. The program will allow the user to interactively design cell structures that implement selected generic arithmetic functions. The concept of systolic array processing will be extended using elements of various complexity and multi-dimensional structures to achieve very high throughput processing using a broad range of kernel functions. Models for multi-dimensional filters will be developed on the RADC RF Transmission Laboratory FASSP. Scattering theory will be used to search for a class of stable n-D filter polynomials and to obtain a design methodology for frequency selective filtering. Time varying n-D filtering will be considered. Newly developed methods for time series modeling will be examined for efficiency using computer simulations. Special attention will be given to the "Single Value Decomposition" approach. New concepts will be sought for signal classification schemes that do not assume similarity.

8. Artifical Intelligence (RO 7.3.10): An approach to adaptive network architectures developed at AFCRL will be utilized to explore local and global adaptive mechanisms. The emphasis will be on goal-seeking, adaptive networks composed of goal-seeking, adaptive components -- an approach that is expected to lead to a better understanding of decentralized, parallel, adaptive architectures. This class of architectures is in contrast to the centralized, serial, non-adaptive architecture now represented by the conventional digital computer.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Provide collaborative computer support for decision making.

b. Improve software production and maintenance through intelligent software assistant.

c. Increase the accuracy and timeliness of information integration and analysis through knowledge-based processing techniques.

d. Provide system timing components which will have lower noise spectral characteristics and higher long term frequency stability.

e. Provide data to assess the feasibility/desirability of exploiting non-conventional HF propagation modes for surveillance and survivable communication purposes.

f. Provide adaptive interference analysis capability to reject unwanted interference.

g. Provide baseline capability to accurately recognize speech to enhance command and control capabilities and communications even in the presence of extreme communication link interference.

h. Improve measurement and detection capabilities of receivers and processors.

i. Realize mobile communication networks which are secure and bandwidth efficient.

j. Reduce the complex digital architecture required for image compression, and extend the image transmission capability to higher data rates and larger images.

k. Realize phase locked loops with extended pull-in range and decreased acquisition time for improved secure communications.

l. Achieve methods for modeling of communication channels leading to increased channel capacity and better communication channel utilization.

m. Improve target detection and identification, and reduce the time and effort of photo-interpreters in finding targets.

n. Reduce software costs due to validation and testing of software, and improve reliability of software; reduce life cycle costs.

o. Improve VLSI design and systematized modular design procedures of general applicability.

p. Customize integrated circuits for low cost systems.

q. Provide real-time image data processing for terminal guidance, command and control systems, and target identification.

r. Achieve fast, parallel algorithms for signal processing, pattern recognition, system modeling, and weapon allocation.

SUBAREA 7.3 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TOTAL FUNDS SPTG SUBAREA 7.3 ($K)
2304A5	Statistics and Probability	3100	300
2304A6	Mathematics of Signal Process.	900	290
2305A8	Information Electronics	715	485
2305A9	JSEP - Electronics	2750	250
2305B1	Optical and Acoustical Processing	2292	1376
2305B3	Digital Information Electronics	641	391
2305C3	Superconducting Electronics	1205	1205
2305J1	Electronic Device & Circuit Research	1309	327
2305J2	Radio Wave Propagation Studies and Computations	639	639
2305J8	Signal Processing	600	432
	TOTAL		5695

AFOSR Focal Point: Lt Col Robert W. Carter Jr
Telephone: (202) 767-4931

TECHNICAL AREA: Electronics

SUBAREA NUMBER AND TITLE: 7.4 Components

GENERAL OBJECTIVE: Research in this subarea encompasses a broad spectrum of special physical phenomena underlying electomagnetic devices and device concepts necessary for the application of contemporary electronic technology to the future needs of the operational Air Force. This includes the exploitation and application of basic phenomena and special properties exhibited by electromagnetic materials (including special processing technology); the controlled modification of electromagnetic phenomena by means of material engineering; and application of findings from theoretical and experimental investigations of electronic, optic, acoustic, thermal, magnetic, insulating, and conduction properties of materials to the evolution of new and improved device concepts.

RESEARCH EFFORTS:

1. Low Power Integrated Microwave Devices (RO 7.4.1): Programs to develop new device concepts and improve performance parameters of existing microwave devices (TUNNETTS, Metal Base Transistors, FETs, OPFETs) are being pursued. Several techniques will be examined. Laser techniques, such as surface enhanced Raman scattering and second harmonic generation will be applied to analyze, on a submicron scale, materials parameters in electronic device fabrication. Photochemical techniques will be applied to materials growth, preparation and processing of microwave devices. The use of light inputs, will be investigated as inputs to novel devices and to phase lock arrays of spatially displaced millimeter wave sources. Heterojunction bipolar transistors with wide band gap emitters will be produced by MBE for microwave and photo-transistor applications. A better understanding of high-speed transport phenomena will be studied to achieve new approaches to minimize the hot-electron effects for low-voltage devices and to improve the breakdown voltages of high-voltage devices. Initial studies will be on the AlGaAs/GaAs system; then attention will turn to InGaP/GaAs heterojunctions. Advanced modeling calculations of heterostructures with varying geometries and compositions will be performed. HEMT devices will be fabricated from MOCVD and MBE grown material to verify theoretical calculations and models.

2. High Power Microwave and Millimeter Wave Tubes (RO 7.4.2): Research to investigate mechanisms that offer the potential of generating microwaves at all levels will be undertaken to develop a deeper understanding of electromagnetic interactions in all classes of microwave devices. Free electron laser techniques will be investigated to produce high power millimeter waves efficiently; and, devices which combine the high gain, transverse bunching characteristics of gyrotrons with the Doppler frequency upshift of free electron lasers will be studied. Nonperturbing probing techniques using various spectroscopic techniques will be used to examine the background gasses in a microwave tube.

3. Integrated Optics and Fiber Optics (RO 7.4.3): We seek to expand the capabilities of integrated optical devices for real-time information processing and to develop micro-optic sources, detectors and wave guides for optical signal processing. Techniques for using optical bistability for very fast logic arrays will be studied, as well as large area thin film nonlinear materials. A new type of III-V compound transient time photoconductor detector with reduced dark current and power dissipation will be developed. Techniques of laser annealing and laser growth of single crystal silicon will be used to create new device structures for integrated optics. Fresnel lenses in high index-of-refraction waveguides such as lithium niobate will be analyzed, designed, fabricated, and experimentally evaluated. Reconstruction methods and volume holographic techniques will be investigated for their capability to improve Fresnel lens performance in such respects as side lobe reduction, better efficiency, and larger signal-to-noise ratios. Another effort will be directed toward optically addressed spatial light modulators for use in optical signal processing. Low threshold and solid state lasers, and lasers with secondary nonabsorbing quaternary layers will be investigated.

4. Advanced Processing Methods for Submicron Structures (RO 7.4.4): The application of laser photochemical techniques for materials preparation and device processing for sub-micron electronics will be explored. Submicron processing by means of controlled nucleation will be studied, as will patterned photochemical growth of films on other substrates, for example germanium on gallium arsenide and zinc oxide on silicon. Soft x-rays emitted from plasmas will be examined for application to high resolution lithography. The efficient production of plasmas, the control of soft x-ray emissions from plasmas and nonequilibrium plasma dynamics will be investigated in regimes that are potentially attractive for high resolution lithography. Laser photochemical doping techniques at high doping concentrations and at very shallow depths will be studied. Another effort involves using MBE to grow GaAs over E-beam evaporated tungsten grids on GaAs substrates, which is a critical step in the production of buried-grid permeable base transistors (PBTs). Techniques for MBE growth and selective etching of single crystal tungsten or aluminum grids with improved properties will be developed. Single crystal garnet and amorphous metal-metalloid films will be grown by liquid phase epitaxy and r.f. sputtering respectively. These films will be modified subsequently by ion implantation and the interdiffusion of surface-deposited materials. Novel approaches to various wet and dry processing techniques will be investigated and used to fabricate micron and submicron-gate FET's on MBE and MOCVD-grown AlGaAs/GaAs heterostructures. Self-aligned gate MESFET technology will also be explored for these ultra thin modulation-doped structures.

5. Electro-Optical and Non-Linear Optical Techniques (RO 7.4.5): Techniques for making nonlinear optical devices using single crystal fibers of nonlinear materials will be continued. Parametric interactions in the visible and IR will be studied to take advantage of the long interaction lengths (hence potentially high efficiencies) available in high quality fibers. Millimeter wave electro-optical techniques will be studied.

6. Coherent Tunable Sources of Electromagnetic Radiation (RO 7.4.6): Research will be conducted to improve the energy recovery of free electron lasers, to examine the applications of wigglers to free electron lasers, and to develop non-linear optical fiber concepts for wavelength conversion. Wavelength conversion schemes based on nonlinear optical fibers will be pursued, including the possibility of driving multiple, coupled fibers with diode lasers. Hybrid techniques, in which glass fibers are imbedded in nonlinear optical materials will be explored. New excitation techniques, and their associated kinetics, will be studied for excimer lasers. Microwave discharges of metal halides will be explored in detail. Nonlinear and two-photon pumping techniques in the vacuum ultraviolet will be studied to extend the wavelength ranges presently available. Growth and nonlinear optical techniques in single crystal fibers will be explored for producing tunable sources in the visible and infrared.

7. Gas Laser Techniques (RO 7.4.7): Candidates for induced collision lasers will be studied, especially excimers. Various gas laser discharge and optical mode coupling techniques will be explored to achieve high power densities in gas lasers. Another area focuses on modeling and analysis studies that will be performed on plasmas containing attaching species, such as occur in the rare gas-halogen and metal-halogen lasers as well as electron beam controlled switches. Stability of the cathode fall region of a discharge will be analyzed in the presence of an electronegative gas. In a related effort, research will be conducted with the final objective of extending current laser operating lifetimes for use in countermeasures. The phenomena that occur at high pulse energies, as well as optimum power conditioning, interfacing, and materials compatibility in a closed cycle electric discharge laser will be analyzed. The kinetics of pulse length and excitation efficiency involved in achieving high repetition rates, and short burst mode operation will studied. State selection of vibrational states in H_2, O_2, and HD will be studied using frequency tripling or quadrupling. Upper level vibrational-vibrational transition rates will be measured.

8. Signal Processing Components and System (RO 7.4.8): Research will continue with the goal of obtaining new realizations of optical digital filters and fast Fourier transform devices which exhibit improved characteristics of speed, accuracy, size and weight. These investigations include dynamic range, roundoff error, and optimum structure for signal processors. Research will investigate optical analog and optical-electronic hybrid computers for solving in real-time the partial differential equations which arise in simulation and control problems. Additional research will investigate optical digital computing of binary bit planes. Concepts for optical threshold devices, converters, and optical logic devices will be pursued. In another effort, modulation-doped AlGaAs/GaAs heterostructures of varying composition and submicron thickness will be grown in-house by MBE, using arsine gas and solid arsenic source of arsenic, and by MOCVD for the purpose of investigating epitaxial layer quality, particularly interface sharpness, as a function of growth parameters and techniques. Heterojunction interface sharpness and quantum-well formation will be investigated by several novel experimental approaches, including topographic Raman Spectroscopy and electron backscattering. Double crystal X-ray diffraction, SIMS, SEM and AES profiling will also be explored.

9. Surface Acoustic, Optical, and Magnetic Wave Device Components (RO 7.4.9): Research will be undertaken to discover new electro-optic solids which are not limited in performance by their growth techniques and by the sensitivity of their optical properties to ionic defects. Thin films (AlN on SOS, InSb on $LiNiO_3$, ZnO on GaAs) of the highest quality will be developed and characterized by advanced sputtering and other techniques for acousto-electric and acousto-optic applications. In addition new polymerization processes will be investigated for the growth of noncentro-symmetric polymeric and organic crystals with large non-linear second-order optical coefficients, large anisotropic birefringence, and excellent mechanical properties. New techniques will be investigated for the growth of improved congruently melting inorganic crystals with expanded compositional ranges. In another effort, advances in the theory of temperature dependent beam steering and diffraction will be made with the objective of obtaining new crystal orientations which are temperature compensated over a wide temperature range. Specific advances will include modeling of finite transducer length and the inclusion of the temperature dependence of the metal transducer films. Voltage variable time delay will be investigated for shallow bulk acoustic waves with faster velocities and therefore higher frequencies than can be achieved with surface acoustic waves. New concepts for voltage variable time delay on piezoelectric semiconductors, such as gallium arsenide, will be investigated. The causes of the experimentally observed very weak piezoelectric coupling of indium phosphide will also be investigated.

10. Frequency Control Devices (RO 7.4.10): Candidates for stored ion frequency standards, using laser cooling, will be explored. Research will also be conducted on the physics of rubidium vapor frequency standards to improve the stability drift and reproducibility of these standards, while maintaining or improving their small size and low cost. Means to reduce environmental effects will be studied as the origins of these effects becomes clear.

11. Sensors and Sensor Technology Improvements (RO 7.4.11): The research objective is to extend the long wavelength cutoff of Schottky Barrier infrared detectors to wavelengths beyond 10.0 micrometers. The platinum silcide processing technology will be extended into electrode thickness ranges between 1 and 10 crystal monolayers. Models for internal photoemission in very thin film photoelectrodes will be developed. An integral focal plane/multiplexer array will be designed based upon the RADC developed self guarded focal plane array architecture.

12. Antennas and Associated Components (RO 7.4.12): An investigation of novel techniques for very high resolution imaging employing very few receiving elements is being conducted. The fundamental principles underlying the design and construction of monolithic low-profile phased array antennas at EHF will be extended to include null-setting adaptive techniques to large phased arrays that are very broadband with low sidelobes and capacity to deal successfully with mainbeam jamming. A new analytical and computer-oriented technique for antenna pattern shaping and broadbanding will be explored. Frequency diversity (multispectral or swept frequency illumination) will be used to enhance the information content of the wavefields scattered by the object and recorded over cost effective mircowave apertures. In a related effort, a new

approach to power pattern synthesis will be tried, using the augmented ray equation obtained by replacing the observables in geometeric optics with operators. An effort will be made to learn how to hardwire signal processing into antenna array design. Also, computer programs will be prepared for array antennas with broadbanding, null-steering, beam-shaping, low-sidelobe and wide-angle scan capabilities, with complete account taken of interelement coupling and prescribed pattern constraints. Measurements will be conducted to demonstrate the effectiveness of phase-only adaptive techniques in the simultaneous null steering in the sum and difference patterns of monopulse antenna systems. Methods of adaptation which incorporate a small number of the degrees of freedom available in a large phased array will be developed and experimentally verified.

13. Device Reliability Techniques (RO 7.4.13): Efforts will focus on the fundamental physical, chemical and electrical mechanisms underlying the degradation of solid state electronic devices and development of new methods for analyzing performance limiting mechanisms in fine geometry Very Large Scale Integrated Circuit (VLSI) microstructures. The response of microelectronic devices exposed to energetic ions found in cosmic rays, solar flares, and other space environments will be modeled.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Improved solid state devices and circuits for signal processing, signal transmission, very large scale integrated circuits (VLSIC) and very high speed integrated circuits (VHSIC).

b. Dual mode, low noise, high reliability, wide band, high efficiency, high power microwave tubes.

c. Secure optical fiber communication systems.

d. Real-time optical signal processor.

e. Lower cost solid state electronic systems by improved device processing yield and performance.

f. Simplified and lower cost imaging arrays for very high resolution reconnaissance and surveillance.

g. Electronically tunable filters for frequency shift keying in secure, anti-jam communications systems.

h. Electronically tunable filters for ECCM protection of broad band, spread spectrum communications receivers.

i. Compact, electronically variable time delay units for beam steering of wideband phased arrays..

j. LANTIRN product improvements..

k. Advanced analog signal processing solid state components.

l. Form theoretical basis of high power millimeter wave tube development.

m. Enhanced understanding of tube life to design more reliable microwave tubes.

n. Compact electronically variable time delay units which replace bulky coax needed for beam steering of wideband phased arrays.

o. Signal processing components at microwave frequencies eliminate hardware presently required to downconvert to lower frequencies (IF).

p. New high throughput analog signal processing elements compatible with digital processors to enhance overall computing capability.

q. Infrared sensing technology based on silicon substrate Schottky barrier detectors for ruggedness, high reliability and ease of manufacture.

SUBAREA 7.4 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TOTAL FUNDS SPTG SUBAREA 7.4 ($K)
2301A1	Optical Physics	5222	2627
2301A4	Atomic and Molecular Physics	1525	220
2301A8	Plasma Physics	3116	540
2301A9	Quantum Electronics (JSEP)	191	191
2301F1	Guidance, Control and Laser Research	385	148
2301S1	Advanced Optical Measurement Techniques	658	183.8
2301S2	Plasma Rsch, Gas Discharges and Laser Plasmas	1240	969.5
2305A9	Solid State Electronics and Electromagnetics (JSEP)	2750	1475
2305B1	Optical and Acoustical Processing	2292	734
2305B4	Optical Signal Processing	1778	828
2305C1	Electronic Component Science	1669	1669
2305J1	Electronic Device & Circuit Rsch	1309	982
2305J3	Electromagnetic Radiators	744	517
2305J5	Microwave Acoustics & Magnetics	947	947
305J7	Optical Signal Processing	250	250
2305J9	Thermionics Research - AFTER	569	569
2305R1	Semiconductor Device Research	1210	1210
2306J2	Optical Circuits Component Rsch	1150	1150
2306J3	Physics of the Interaction of Radiation w/Matter	744	744
2306J4	Device Reliabiility Research	773	773
	TOTAL		16727.3

AFOSR Focal Point: Lt Col Robert W. Carter Jr
Telephone: (202) 767-4931

TECHNICAL AREA: Electronic

SUBAREA NUMBER AND TITLE: 7.5 Electronic Warfare

GENERAL OBJECTIVE:

Electronic Warfare (EW) involves the use of electromagnetic energy to determine, exploit, reduce, or prevent hostile use of the electromagnetic spectrum while retaining friendly use of the spectrum. The continued introduction of sophisticated electronic systems and devices has resulted in the inclusion of electromagnetic warfare into all levels of conflict intensity from peacetime applications such as gathering of intelligence to wartime application of both tactical and strategic nature. Electronic Warfare historically has been reactionary in nature since the countermeasures to enemy weapons systems typically exploit specific operating characteristics of the enemy systems that are not known adequately until the weapons are encountered. A robust technology base is mandatory to achieve a short reaction time from first appearance of enemy weapons systems to first fielding of effective countermeasures. The goal of the research program is to provide, at a minimum, the knowledge base to support exploratory development of countermeasures to known or suspected weapons systems and ideally to provide generic solution, independent of specific weapon system characteristics.

RESEARCH EFFORTS:

1. IR/Laser Countermeasures (RO 7.5.4): Research will develop new materials and material combinations to generate absorbing and obscuring smokes suitable for use in the space environment. Also it will be aimed at an improved understand of the processes of evaporation and condensation in the space environment and their bearing on production of obscurants and performance of high temperature refractories for spacecraft protection. The mechanisms by which smoke clouds form and disperse in space will also be examined. Materials systems used in generating atmospheric smokes to determine how they may be modified to perform in space. Understand and model the differing performance expected of smokes in vacuum (as opposed to suspended in air) will be modeled; and, new materials systems for generating smokes in a vacuum will be devised. Research will study the processes of evaporation of atoms from refractory materials, including photo-evaporation under laser irradiation, and condensation to make microscopic particles. Ways will be found to change the kinetics of evaporation and condensation so as to modify the mechanisms which form smokes and to modify absorption coefficients to reduce the surface temperature of material during high temperature evaporation. Test whether ionization, electromagnetic fields, or other forces can be used to affect the formation and dispersal of clouds of obscuring smokes in space. Interaction with solar radiation, residual atmosphere and the geo-fields will be examined to understand what space environments can do to obscurant clouds.

2. Microwave Component Modelling (RO 7.5.6): Research efforts will be devoted to three areas: nonlinear microwave components analysis, frequency multiplexing, and microwave amplifiers. The relationship between the devices used in the components, the performance of the component, and the impact on microwave receivers will be established. The performance of each component for microwave receiver applications will be optimized through variation of devices and circuits used in the design. Different approaches to accomplish frequency multiplexing will be studied and compared with predicted performance. Various schemes of connecting individual microwave bandpass filters into a filter bank will be examined including electrical, mechanical, surface acoustic wave (SAW) and bulkwave filter types. The characteristics of microwave amplifiers will be determined from the basic physics of the transistors and circuits used in the amplifiers. A microwave MESFET amplifier model including both high frequency and nonlinear effects will be developed. In addition, high electron mobility transistors (HEMT) will be examined for microwave applications.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS

a. Achieve increased protection of aircraft from infrared guided missiles through the use of infrared absorbing smoke.

b. Provide baseline understanding of the ability of smoke and obscurants to protect spacecraft from antisatellite weapons including high energy lasers.

c. Provide the analytic tools for the improved design of microwave receivers for Electronic Warfare (EW) applications.

d. Provide the technology base for multiplexing frequency effectively which is a major deficiency in many EW receivers.

e. Provide the technology base for designing microwave amplifiers to meet performance criteria.

SUBAREA 7.5 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TOTAL FUNDS SPTG SUBAREA 7.5 $K)
2305R4	Microwave Component Modelling	500	390
2306C4	Spacecraft Survivability	1240	680
	TOTAL		1070

AFOSR MANAGER: Dr David W. Fox
Telephone: (202) 767-5025

TECHNICAL AREA 8: Computational Sciences

INTRODUCTION

The Computational Sciences Technical Area describes that part of the AFOSR research program that supports the design, understanding, and use of computers and computing in Air Force technology. Large digital computers have become indispensable in the design and analysis of high performance weapons and vehicles, and microprocessors have become imbedded in many real time systems such as those for digital communications, weapons management, and flight control. Not only does computation provide the means by which Air Force systems are designed and engineered, it provides the understanding to operate and maintain them, and more and more it supplies and supports the intelligence on which decisions and strategies are based.

This is the first year in which Computational Sciences has been reported as an integral part of this Plan. Due to the presence in other technical areas of topics now included in Computational Sciences (e.g., automatic speech recognition), some funding which might be accounted for under Computational Sciences is catalogued elsewhere. In succeeding years this will diminish as duplications in other technical areas are eliminated.

FY 86 PLANNED FUNDING:

MAJOR THRUST INITIATIVE:	FUNDING ($K)
Distributed Parameter Control	1500
TOTAL	1500

SUBAREA NUMBER	TITLE	FUNDS SPTG SUBAREA ($K)
8.1	Computer Structure and Design	1665
8.2	Computer Science Techniques	3650
8.3	Numerical Computation Methods	3848
8.4	Computational Models and their Applications	4460
	TOTAL	13623
	TECHNICAL AREA TOTAL	15123

AFOSR Focal Point: Dr. Marc Q. Jacobs
Telephone (202) 767-4940

TECHNICAL AREA: Computational Sciences

MAJOR THRUST INITIATIVE: Distributed Parameter Control.

GENERAL OBJECTIVE:

The objective of this initiative is to develop analytical tools and computational algorithms for identification, control and optimization of systems modeled by partial differential equations, functional differential equations, or integro-differential equations. At present most controller design for these distributed parameter systems is done by using lumped parameter models to approximate the true spatially continuous system. To overcome the critical defects which one might expect when ad hoc approximations are introduced into the modeling process, it is necessary to study control design methods which are based on more realistic distributed parameter models of various physical processes of interest to the Air Force. As a result of this research, it will become possible to develop improved techniques for control, identification and optimization of flexible space structures, aeroelastic systems, combustion models, fluid flow, flexible robotic arms and thermodynamical systems.

RESEARCH EFFORTS:

1. New methods will be developed for mathematically modeling and analyzing those distributed parameter systems which govern combustion and general propulsion systems. Better distributed parameter models of combustion and general propulsion systems will be used as a basis for studying control design for these systems. Infinite dimensional state space models will be used to develop numerical models for simulation and control.

2. The goal is the development of feedback control laws for stabilization and control of flexible structures such as wings, space structures and robotic arms. New theoretical results on stabilization through boundary input and closed looped infinite dimensional systems will be developed and analyzed. Research will be performed using the theory of operators and semigroups in Hilbert spaces. Topics include pole assignment in infinite dimensional state space systems and stabilization of boundary input control systems. Control systems that are bilinear in the state variable and control variable will be studied. Approximation techniques for identification and control of partial and functional differential equations will be studied.

3. Develop distributed parameter models; analysis techniques and approximation schemes for the design of actual controllers for flutter suppression and lift enhancement. This includes improved aerodynamic and structural modeling, and computational methods for identification of aeroelastic systems. This work will make use of recent results in the modelling of air foils in unsteady aerodynamics as dynamical systems. New methods in stability analysis, approximation and identification of dynamical systems will be developed and applied to the modelling and control of aeroelastic systems. Recent infinite dimensional state space models will be used for the design and analysis of the identification and control algorithms.

4. The goal will be to develop numerical approximation schemes for partial and functional differential equations that model structures, fluid flow and aeroelastic systems which lead to efficient computational algorithms for simulation of large distributed parameter control systems. The primary goal of this research is the development and analysis of fast numerical algorithms for control of infinite dimensional systems that can be used as a basis for real time control of future Air Force systems. Development of fast and convergent numerical algorithms for parameter estimation in control systems modeled by integro-differential equations, partial differential equations and functional differential equations. Finite element, finite difference and projection methods will be used to construct simulation models for control systems governed by distributed parameter models. Rigorous mathematical analysis will be used to systematically analyze these methods to insure that the numerical model is appropriate for simulating model closed-loop systems, and computing gains. Recent advances in parallel computing, infinite dimensional approximation theory and mathematical modeling will be used to analyze new numerical algorithms for computing feedback gain operators. Functional and numerical analysis will provide the framework to compare theoretical convergence rates and numerical simulations will be used to test the theoretical error bounds. New quasi-Newton algorithms for infinite dimensional optimization will be applied to parameter estimation problems where the control system to be identified is governed by a distributed parameter model. Semi-discrete and fully discrete approximation methods will be applied to these problems. Convergence and computational efficiency of the algorithms will be studied both theoretically and through computational experimentation.

5. The goal is to develop new approximation techniques that can be used to construct models for identification control and optimization of systems governed by partial differential equations, functional differential equations and integro-differential equations and to analyze these approximate models to assess potential benefits and limitations of each model. Research will be performed using the theory of operators and dynamical systems in Hilbert spaces. Topics include state space modelling of aeroelastic systems, of large space structures and of optical devices, approximation of infinite dimensional systems and large scale computing. Finite difference and finite element techniques will be used to develop computational tools for identification and control of these systems.

Total Task Funding: $1500K

AFOSR Focal Point: Capt John P. Thomas, Jr.
Telephone (202) 767-5026

TECHNICAL AREA: Computational Sciences

SUBAREA NUMBER AND TITLE: 8.1 Computer Structure and Design

GENERAL OBJECTIVE: This subarea supports research that leads to innovations and improvements in the conceptual design of computers to fulfill Air force needs. One part of the investigations examines the possibilities and problems that arise in using various degrees of parallelism in computers. Strictly serial and massively parallel structures form the extremes, but understanding of intermediate structures and of reconfigurable and adaptive architectures is needed. These issues are closely related to questions that arise in dealing with networks and hierarchies of computers that may be close or remote. For example, techniques for assessing network reliability are essential for efficient and secure functioning of decentralized systems. Distributed systems offer the potential of increased reliability and greater processing capacity than single processor systems. Emphasis in this area is on discovery and understanding of fundamental algorithms that can execute on networks of asynchronous, communicating processors and on finding techniques for avoiding or detecting deadlocks. Another important question is how computers with millons of active elements can be made tolerant of the defects that occur. At least in the first few years the chips with micron-sized components may have a significant fraction of defective elements. Closely related questions involve self-diagnosis and self-repair in computers. The nearly infinite possibilities of VLSI require special methods for efficient layout and mask designs. Techniques of graph theory and artificial intelligence show promise in greatly speeding up the process.

RESEARCH EFFORTS:

1. Fault Tolerant Architecture (RO 8.1.2.): Additional work is needed on the theoretical foundations for fault-tolerant VLSI design. Important factors to an efficient, effective VLSI design include the crossing number of a graph, the layout area of planar graphs, channel routing, computational complexity and programmable logic arrays. Design algorithms incorporating these factors are needed.

2. Computer-Communication Networks (RO 8.1.3.): In the area of computer communications network design, the intention is to employ the methods of graph theory, probability theory, and combinatorial analysis to the fault tolerant design of communication equipment and networks for command and control. We want to find models which can be used effectively to discover the best methods for reconfiguration and recovery after a fault is found. Also, we hope to develop novel random access algorithms for a single channel with multiple bursty users. The intention is to design multiple access communcation algorithms whose performance is robust in the presence of changing input traffic.

3. Computer Architecture (RO 8.1.1.): In the area of multiprocessor architectures, approaches toward parallel architectures will be considered at simulation and prototype levels. The architectures will be evaluated in part relative to their effectiveness when applied to problems in computational linear algebra that arise in the solution of ordinary and partial differential equations from the physical sciences. For artificial intelligence

applications, we want to develop advance software and hardware architectures for knowledge-based systems which will overcome fundamental limitations in current knowledge based implementation, management and maintenance techniques. Methods leading to the development of software ahd hardware architechures to support efficient logic programming will be emphasized.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Develop design algorithms for fault-tolerant VLSI circuits taking into account such critical issues as the crossing number of a graph, the layout area of planar graphs, and channel routing.

b. Produce novel computer architecture concepts such as parallelism which will allow a scaling-up of the computing power to a level needed for solving currently intractable computer simulations for Air Force application codes.

c. Develop advanced computer software and hardware capable of overcoming current limitations in the implementation of knowledge-based systems.

d. Produce reliable software for the control and execution of programs on decentralized systems employed in many Air Force computer networks.

SUBAREA 8.1 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 8.2 ($K)
2304J5	Artificial Intelligence (Univ Consortium) Research Pgm	805	175
2304A2	Computer Science	1720	540
2304A5	Statistics and Probability	3100	225
2304B1	Finite Mathematics	750	300
2304A3	Mathematics of Computation	3000	100
2304A7	Artificial Intelligence	1915	325
	TOTAL		1665

AFOSR Focal Point: Dr Robert N. Buchal
Telephone (202) 767-4939

TECHNICAL AREA: Computational Mathematics

SUBAREA NUMBER AND TITLE: 8.2 Computer Science Techniques

GENERAL OBJECTIVE: The Computer Science Subarea focuses on discoveries that could prove useful in future military systems for command and control, communication, intelligence, data handling, avionics, and guidance. Computers ranging from custom VLSI chips to large scale systems are hoped to make possible the anticipated sophistication and capability of these systems. Engineering such systems requires the ability to match algorithm and hardware to the character and size of the problem to be solved. Existing computer science techniques have limitations which are often only partially appreciated. The general objective of this RO is to explore, characterize, alleviate, and if possible surmount these limitations with regard to those problem areas of Air Force interest. To achieve the human level of performance on tasks like natural language understanding using incremental extensions of existing computer science techniques may not be possible. Thus a long term objective is the creation of new paradigms to capture the essence of intellectual activity in a form independent of whether the activity occurs in a computer or in a neural net.

RESEARCH EFFORTS:

1. Computer Software and Security (RO 8.2.1): Software Sciences Technology is concerned with the data processing requirements for the design, development, and optimization of high speed, high capacity information processing systems, and associated support software, to provide effective, real-time support to the Air Force's mission. The rapidly growing cost of software requires continued research to find more productive and reliable methods for developing software. Research in the area of advanced higher order programming languages and software engineering includes the development of efficient compilers, integrated programming environments, knowledge-based systems, and techniques/tools for life-cycle testing/verification/validation, quality measurement, and cost estimation. The area of Automatic Programming develops practical systems that automatically generate routing programs from a minimal input specification or are able to automatically perform major modifications on existing programs. Ultimate long-term orientation is to handle inputs from non-professional programmers in a loose format, context-free environment. Immediate results, understandably, will have more rigid constraints. Current philosophy ties the principle of this field closely with those of semi-automatic, assertion-oriented program verification. However, an impasse as to the size of permitted programs appears likely; as program size increases, the theorems and proofs of the theorems grow exponentially. Therefore, alternative methods to those that currently exist are necessary for automatically generating and proving theorems for large-scale programs. Theoretically defining and specifying the semantics of data and the semantic operation of computer programs, and in formally specifying the functional requirements the systems must fulfill is important to the automatic generation of programs. A comprehensive, well-integrated and

easily understood theory of security related to automated information processing systems needs to be developed. The theory needs to incorporate mathematical models of compromise, integrity and denial of service, and has to include use of software tools and techniques to formally demonstrate that complex systems correctly implement a stated policy in an insubvertible manner. The models, tools, and techniques must be applicable to both single and distributed processing systems. Specific goals include the following: Investigate and evaluate techniques for referencing written computer programs. Investigate software construction using and reusing components to expedite the programming process. Investigate fundamental algorithms suitable for execution of a network computer and languages for expressing the distributed algorithms. Investigate application generators for use in large scale software development. Establish theoretical foundations for recognizing and avoiding deadness errors arising with cooperating and communicating processes. Investigate a single coherent approach to analyzing the performance and correctness of distributed systems at both the hardware and software level. Investigate algorithms that can make NP-complete problems tractable "on the average." Postulate and evaluate metrics for software and software engineering techniques. Investigate methods of rigorously and unambiguously specifying software requirements. Investigate deduction or automated theorem proving techniques for transforming functional specifications of computer programs into specific programs that implement the specification. Develop formal methods especially for specification and verification. Modular software is a major objective. Develop statistical techniques of modeling and inference for software failures.

Possible approaches include the following: Specify a program reference language providing a uniform framework for access to programs using either textual, string match, syntactic, contextual or historic references or any combination of these reference types. This promises to make program manipulation by humans more concise, efficient and flexible. Develop the concept of "meta program" denoting simultaneously a class of implementations with the same abstract behavior. Software construction using components promises increases in programmer productivity. Investigate distributed languages suitable for expressing operating system level algorithms such as two phase commit, distributed deadlock detection, resource allocation problems, and multiple copy updates on network computers. Loosely coupled algorithms which tolerate malfunctioning devices and inconsistent information should be investigated. Design a language for describing programs to be input to an application generator. Describe and categorize the types of errors that can occur on distributed systems in the general case where the system may contain dynamic activation on parallel threads of control. Both design rules to preclude deadness errors and execution monitoring to detect a deadness error and invoke "evasive action" must be considered. The specification of a process should deal only with the manner in which a process interacts with its environment. The specification technique should be evaluated by investigating its ability to describe the operation of several distributed systems, by attempting to prove both the partial and total correctness of systems described by the technique and by investigating methods of predicting system performance from the specification. Experiments with algorithms for the NP-complete problems using randomly generated inputs might identify key parameters of the input distribution determining inputs for which the algorithm is best suited. Software engineering should be set on a firm

scientific basis. Areas of investigation include issues of language support for distributed, real-time and embedded computer systems, and empirical studies of software development. If a theorem-proving program can produce a constructive proof of existence of an object and the proof satisfies certain properties then a program producing the desired output may be extracted from the proof. Knowledge of the subject matter of the desired program, of the language in which the program is to be expressed, and of the skills and techniques of the programmer are represented as the axioms and rules of the deductive system that proves the theorem. This method of construction provides an implicit proof that the program satisfies its specification.

2. Expert Systems (RO 8.2.2): Understand the structure of knowledge and reasoning processes for producing computer based expert decision making consultation systems, that permit utilization of the computer in a collaborative manner capturing the diversity and complexity of human expert reasoning in real world problems.

Possible approaches include the following: Investigate paradigms to deal with problems not explicitly covered by the rule base, permit additions to programs without requiring skilled programmer intervention, make constructing the knowledge base easier and less time consuming, etc. Identify generic tasks such as classification (useful in diagnostic reasoning), state abstraction (useful in answering questions of the type, "what will happen if [action] is taken on the system") "intelligent" information passing (useful in certain kinds of data retrieval problems), and hierarchical plan refienement (useful in certain types of design problems) together with the appropriate knowledge representation and control strategies.

At Rome Air Development center inhouse work includes the following: Develop an expert system supporting mission planning based upon extensions to existing KNOBS software.

3. Data Base Design (RO 8.2.3): Data base systems function as repositories of data, data collectors, data communications, data organization and storage processors, and information retrieval and display systems. These functions should be coordinated to ensure effective, efficient, and economical operation of the total system. In its primary function as a repository of data needed for strategic, intelligence or tactical data processing, the data should be accurate, private, protected from damage and organized so that diverse users (with different data requirements) can utilize it. To do this, research should be emphasized in data base management systems, distributed data bases, high level user interfaces, data format and linkages, inferential rules for intelligence data bases, and any other pertinent technical considerations which impact the processing of data in an accurate and timely manner. The specific goals address basic knowledge representation and reasoning (developing and evaluating new general techniques independent of any particular knowledge domain for representing knowledge and for reasoning with knowledge). Specific goals include the following: Discover techniques for representing large data bases of diverse types such as variable length text, icons, and spatial data. Develop methods for expressing computer based knowledge by generating multisentence and multiparagraph English text to meet the needs of the untrained data base user making the request. Examine techniques that will allow users to view a data base as a single "universal" table and free users from the need to understand the internal representation of the data base. Develop logic programming formalisms including parallel logic systems within which to program and maintain complex data base applications.

Possible approaches include the following: Extend the relational data base model to handle diverse data types and use a browsing paradigm for searching the data base. Text generation requires availability of four distinct types of information: (1) knowledge which existed before the need for the text was encountered (i.e., subject matter); (2) knowledge which was generated in order to meet the need but before the grammar was entered; (3) knowledge which was available to the grammar on demand, without anticipation; and (4) goal(s) to be achieved by the text. Use of this decomposition makes it possible to isolate some of the problems of text generation to particular kinds of knowledge supply and to simplify the collection of planning processes which are needed to prepare for generation. Demonstrate a data management system capable of interpreting queries on the universal table and of assisting the data base designer in selecting underlying tables and in specifying the rules whereby query interpretation can be conducted. Investigate paradigms to characterise systems that represent and reason about their own beliefs, to represent the basic concepts such as time, space, or knowledge, and the way these concepts are conveyed in natural language in a form amenable to computational manipulation and automated inference, to exploit inherent parallelism whether by making parallel existing sequential codes by mappings to the physical architecture or by developing entirely new logical paradigms, etc.

4. Artificial Intelligence (RO 8.2.4): The aims of this discipline include the development of computer systems and concepts that help people solve difficult, usually non-numerical, problems. Computers can be used now to play expert chess, to perform complicated mathematical formula transformations and simplifications, including the evaluation of indefinite integrals in closed forms, and to provide expert medical consultation in the treatment of bacterial infections. Potential military uses include computer assistance or training in the maintenance and repair of complex weapons systems, electronic systems, and vehicular systems, as well as a variety of C^3 applications such as providing an intelligent interface between the military personnel and the more conventional computer programs, for the quick translation of immediate requirements into computer action. Research is needed in all phases of the art, including knowledge representation, tree search methods, means-end analysis, natural language processing, image analysis, data base management, and expert systems. Specific goals include the following: Demonstrate the feasibility of automatically generating programs for concurrent execution. Investigate techniques for parsing or recognizing in a natural and robust way input to automated systems. Investigate feasibility of large intelligence systems capable of performing useful tasks with reasonable performance and investigate techniques for large systems composed of a collection of smaller intelligent subsystems. Develop basic image understanding models, techniques for correlating multiple images, fast algorithms and computer architectures for real-time image understanding, and integrated image understanding systems. Modeling activities include identifying and investigating specific steps in the understanding sequence to transform an image array into a semantic description of the content of the image, developing and evaluating new models relevant to image properties and to the steps in the analysis of images, and investigating, developing and evaluating higher level representation of images. Image correlation activities emphasize investigating techniques for identifying corresponding points in different images for the purpose of constructing a large image from a collection of images containing overlapping portions of the larger image, deriving three dimensional information using stereographic analyses, detecting moving objects

in a time-varying sequence of images, and detecting changes in multiple time-varying images of the same scene. Investigations into fast algorithms and computer architectures for real-time image understanding are directed toward enhanced algorithms for image understanding activities and new processors for image understanding that will permit the real-time (where images are generated at video speeds) analysis of images. Investigations of integrated image understanding systems are directed toward complete image understanding systems capable of interpreting images. Develop, if possible, a domain independent theory of constraint and expectation - directed reasoning involving approaches such as hierarchical knowledge representation, multiple levels of abstraction, search, and search operators, and dealing with limited resources and very large knowledge bases. Explore utilization of inference techniques to develop maintenance of reason methodologies which will provide behavior assessment under change for large, volatile knowledge bases whose structure may correspond to formal logic or to more traditional, ad hoc representations. Explore extension of primitive knowledge acquisition techniques to support automated acquisition, integration and maintenance of a global understanding of a complex process from multiple, distributed local perspectives. Develop mechanisms that will enable the system to acquire, model, interpret and record information necessary for generating a natural language description or explanation of past and present task states, including actions and decisions leading to the particular state of the system.

Possible approaches include the following: The approach to developing an intelligent system for program synthesis is to consult "expert" sources of programming knowledge such as experienced programmers and textbooks. This knowledge is carefully codified as a collection of rules represented in a form usable by computer. This will be done for concurrent programming knowledge and techniques. No single parsing strategy seems adequate to parse all desired inputs. A system architecture will be developed to allow several parsing strategies in an attempt to process deviant input. Investigate domain independent and, if possible, parallel paradigms for automatically generating a sequence of steps for achieving some stated goal including a formalism for representing domains, and dealing with constraints. For example, the representation of constraints might include knowledge of a constraint's importance, its sphere of relevance, its interdependencies with other constraints and the possible ways in which it can be relaxed if it cannot be satisfied, including an indication of the relative preferences among the alternatives. Investigate image understanding paradigms with special attention to the computer algorithms (parallel if possible) used to process the image and to the design of expert systems for understanding the image. At the conceptual level a paradigm might involve the transformation of the image data into an abstract internal representation of the visible objects in the scene using cues like color, texture, shape, or motion, expectations about general classes of scenes, etc. Approaches to handling the uncertainty in the results of measurements and transformation such as the Shafer - Dempster theory of evidence would seem appropriate in this context. Investigate biologically based paradigms for Artificial Intelligence. To some extent the slowly growing understanding of the functioning of the brain, eye, etc., can aid in formulating such paradigms. For example image understanding paradigms involving interpertation of image contours or texture changes have benefited from a knowledge of what information is made explicit in human vision and what processes subserve the extraction of that information, resulting in a representation of the image with appropriately reduced information content. Address the problem of providing basic automated machinery for the management of large, complex and highly volatile knowledge bases, especially the maintenance of consistency and integrity constraints utilizing the point of

view of certain logic programming systems, such as the "meta-level" systems, primarily embodied in a system called metaProlog. Develop understanding of the four major areas - interpretation/planning, knowledge representation, knowledge acquisition, and natural language input and generation related to the central theme of acquiring detailed, dynamic models of user activities in distributed tool-oriented environments and using these models to provide assistance and explanation. Address fundamental questions in distributed knowledge acquisition by trying to represent and dynamically acquire the "global" understanding of user activities necessary for developing an "intelligent assistant".

At Rome Air Development Center inhouse work includes the following: Develop an advanced object-oriented simulation language and demonstration system simulating air and ground combat utilizing the superior software environment of the LISP machine.

Application to the Air Force Technology Programs:

a. Provide collaborative computer support for decision making.

b. Integrate expert systems technology for Air Force applications.

c. Increase the accuracy and timeliness of information integration and analysis through knowledge-based processing techniques.

d. Provide improved performance and functional capability of future Air Force C^3I knowledge-based systems.

e. Increase the utility of knowledge-based systems to support both human and automated experts in the performance of unique/specialized tasks.

f. Develop tools and methodologies for the evolution of an "intelligent assistant"/intelligent interface capability, which could be applied to the Air Force C^3I software development environment.

SUBAREA 8.2 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 8.2 ($K)
2304A2	Computer Science	1720	1180
2304A5	Statistics and Probability	3100	50
2304A7	Artificial Intelligence	1915	1590
2304J4	Advanced Computer Processing Research	200	200
2304J5	Artificial Intelligence (Univ Consortium) Research Program	805	630
	TOTAL		3650

AFOSR Focal Point: Capt John P. Thomas, Jr.
Telephone (202) 767-5026

TECHNICAL AREA: Computational Sciences

SUBAREA NUMBER AND TITLE: 8.3 Numerical Computational Methods

GENERAL OBJECTIVE: The goal of the research supported in this subarea is to discover new algorithms for numerical computation, to understand useful numerical methods more completely, and to modify and to adapt computational techniques to obtain greater computing effectiveness. Innovation in numerical methods coupled with rapidly increasing computational power and decreasing computer size is revolutionizing the applications of numerical modeling. The development of new and highly efficient algorithms is needed to take full advantage of great efficiencies potentially possible in vector and in highly parallel processors. The methods adapted to new computing engines require much additional analysis to elucidate fully the effects of concurrent computation. The invention and understanding of a numerical algorithm is completed by the creation of research-level software that implements the numerical procedure on some class of computing machine. This puts an algorithm in a form in which its effectiveness can be observed and that allows it to be shared easily with coworkers. Areas in which improved numerical analysis and algorithm design will lead to better design tools include computational fluid dynamics, structures, and computational physics.

RESEARCH EFFORTS:

1. Numerical Methods for Initial and Boundary Value Problems (RO 8.3.3.): Work is needed in the research area dealing with numerical methods for initial and boundary value problems. The objective of this research is the development and analysis of numerical schemes for the solution of ordinary, partial and functional differential equations that describe flight vehicles, fluid flow, aerodynamics, elastic materials and large flexible structures. The goal is the construction and understanding of improved efficient and robust algorithms for complex systems. Existing algorithms will be modified to be made more efficient on the emerging vector and parallel computer architectures. A more radical approach will also seek the development of entirely new algorithms to exploit more completely any inherent parallel structure. In the case of scientific computing, use of the parallel architecture will be considered for each level of a numerical approximation of a mathematical model.

2. Computational Linear Algebra (RO 8.3.4.): Efficient algorithms for solving the computational linear algebra resulting from the discretization of systems of equations and from signal processing applications need to be explored. The ultimate goal in this area is to obtain more efficient and robust methods for the solution of the algebraic equations which are the end product of most numerical methods. One objective is to exploit the special matrix structure inherent in many discretization approaches. It also seems clear that future efforts in this area must address the fundamental issue of how to develop solution techniques for the linear algebra which are well suited for exploiting the emerging parallel processing architectures.

3. Algorithms and Computational Structure (RO 8.3.5.): Numerical algorithms need to be examined from the point of view of their computational structure. The objective is to consider approximate methods for problems from diverse applications as assembled in a complete algorithm, and to consider at the various levels of construction the impact of the new and future parallel architectures for large scale scientific computing. Thus, the full range of the approximation needs to be evaluated in this parallel computing environment so that new methods which optimize the allocation of computational tasks among a number of processors are available to exploit the novel architectures.

4. Software for Numerical Applications (RO 8.3.6.): Research-level software for the integration of a numerical procedure into a sophisticated user environment needs to be developed. The intention is to ease the traditionally significant burden of such tasks as the choice and generation of an appropriate grid and the details of output data analysis. The software should allow for sophisticated interaction by the user in the choice of solution methods, the selection of grids or elements appropriate to the geometry at hand, and in the analysis of the resulting data. In particular, we intend to create efficient, accurate, and user-friendly research level-software for the numerical simulation of multidimensional problems containing plasma and electromagnetic fields in complex geometries.

5. Numerical Methods for Parameter Identification and Control and Optimization (RO 8.3.7., 8.3.8.): With the advent of high speed digital scientific computers, numerical implementation in real time of modern control methods is becoming more and more feasible. Moreover, new super scientific computers provide a powerful tool for designing and analyzing control and optimization techniques for increasingly complex systems. The use of vector and parallel processors for control of flight vehicles and distributed parameter systems such as large space structures requires that basic research be conducted to develop fast and efficient numerical algorithms for control, estimation, filtering and optimization of dynamical systems. Nonlinear optimal control problems lead to very sensitive multi-point boundary value problems. Research in fast and stable numerical methods for solving such boundary value problems is needed. The goal of this research is to develop numerical algorithms for control and optimization of lumped and distributed parameter systems.

6. Simulation and Data Interpretation (RO 8.3.2.): In the area of simulation and data interpretation, we hope to understand different sampling schemes and their rates of convergence for engineering simulations such as tactical and strategic war games. We want to develop efficient signal processing procedures using data compression and construct robust algorithms for filtering and smoothing.

7. Optimization Techniques (RO 8.3.1.): With the advent of geometric shemes for solving large linear programming problems in polynomial time, opportunities to apply these new fast algorithms to problems heretofore considered computationallly intractable must be pursued. The possiblity of extending these algorithms to convex programming problems will be explored. Advances in technology, e.g. in communications networks, computational images, and VLSI designs, have created a wealth of problems whose formulations involve thousands of variables. Even the fastest general purpose algorithms cannot cope with such large problems. It is therefore necessary to develop special

techniques which take advantage of the structure of some of these large problems so that it becomes possible to solve them. We will continue to develop fast algorithms for nonsmooth optimization problems for application in a variety of control systems. Progress in nonlinear programming also will require that we study applications of sequential quadratic programming to a variety of large scale optimization problems. Considerable research remains to be performed in the areas of globalization of algorithms and the proper techniques for handling inequality constraints.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Provide computational tools to be incorporated into design/production codes for applications in structures, fluid mechanics, physics, etc., which can be effectively used on the most powerful computers available.

b. Develop new optimization tools to provide practical solution to solve programming problems for the design of communications networks, VLSI circuits, and resource and battle management.

c. Improve signal processing procedures using data compression and design better algorithms for filtering and smoothing.

d. Provide effective control techniques and their associated computational approaches for use in increasingly complex weapons systems and aircraft designs.

e. Develop sophisticated software to aid in the computational simulation process, including the set-up of appropriate grids, "black-box" solvers, and data analysis.

SUBAREA 8.3 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 8.2 ($K)
2304A1	Mathematics of Dynamics and Control	2250	925
2304A3	Mathematics of Computation	3000	1875
2304A5	Statistics and Probability	3100	200
2301A8	Plasma Physics	3116	265
2304A8	Mathematical Optimization	900	300
2304A9	Applied Analysis	883	283
	TOTAL		3848

AFOSR Focal Point: Dr. Marc Q. Jacobs
Telephone (202) 767-4940

TECHNICAL AREA: Computational Sciences

SUBAREA NUMBER AND TITLE: 8.4 Computational Models and Their Applications

GENERAL OBJECTIVE: This subarea supports computer techniques in their practical use in dealing with the real world. These uses include gaining insight into processes that take place in the physical world, designing devices to manipulate or monitor the real world, and controlling the use of such tools over a wide range of conditions. Often well-understood techniques must be greatly modified to tailor them to deal with applications due to practical constraints. Such modifications often take the methods far from their original domain of consideration and raise new hard questions about their properties and utility. The main use of computers in applications has been numerical in nature, but increasingly computer science methods that manipulate symbols are coming into play. Some techniques are appropriate on super-computers, and some are dictated by the restrictions of microcomputers imbedded in weapons systems. The implementation of finite difference and spectral method algorithms in the setting of computational fluid dynamics is relatively straightforward; however, modifications to tailor automatic grid generation to problems of interest to the fluid dynamics community present challenges. Similarly, the use of artificial intelligence based symbol manipulation programs can, in principle, be used to generate programs for numerical approximations to the solution of partial differential equations used in engineering, but the transition from possibility to widespread practice is not yet clear. The use of large scale computation opens up areas of statistics and reliability modeling that would not otherwise be feasible. Recently developed "jack-knife" methods demonstrate the power of techniques of this sort. Other especially adapted techniques for big computations are the strategic war games. On the other hand, the ability to do significant computations in real time in small spaces opens up the areas of control and signal analysis to rapid innovations in practice. There are many new possibilities with on-line microcomputers. One of potentially great military significance involves switching in communications systems. Packet switching techniques with acknowledgments may give rugged robust systems by using radio networks of many redundant repeaters. These should have high survivability in hostile environments. This subarea also supports experimental computation intended to reveal new mathematical phenomena. Successes in this area, such as the discovery of solitons and of chaotic behavior of simple systems, suggest that numerical mathematical experimentation may prove as stimulating to theory as physical experimentation.

RESEARCH EFFORTS:

1. Models for Numerical Calculation (Floating Point)(RO 8.4.5.):
Experimental computation intended to reveal new mathematical phenomena has yielded new insight, especially into nonlinear processes. Examples include the soliton and phenomena related to chaotic behavior of simple systems. A major goal is the construction and use of such models to investigate physical processes as they arise in such disciplines as fluid and structural simulation, modeling for antenna problems, radio wave propagation, and geophysical modeling. The computational aspects of fluid and structural mechanics need to be more fully developed, particularly the interaction

between the methods and the nonlinear behavior exhibited by the solutions. Develop new generic mathematical techniques for dealing with the nonlinear mathematical models of science and engineering. New phenomena being discovered through numerical experiment on simple systems are leading to new mathematical concepts and theorems and to new scientific paradigms. The rate of discovery of new mathematical phenomena such as solitons, chaos, and intermittency has increased with the increasing availability of small personal computers. By experimenting with these phenomena in their simplest context, insights are being obtained which are resulting in theorems which incorporate and connect ideas from pure and applied mathematics. The resulting paradigms are being investigated by scientists and engineers who hope they may cast some light on well known intractable problems (chaos/turbulence) or suggest new models for real world pheonomen (solitons/elementary particles in physics). More classical phenomena such as bifurcation are also being investigated. Classical nonlinear equations such as those for transonic flow, laser focussing, etc., exhibit certain kinds of singular behavior for which effective mathematical technique is not available. In some cases numerical simulation has cast light on the behavior which has led to analytic insight.

2. Models for Non-Numerical Calculations (Symbolic and Fixed Point) (RO 8.4.6.): A small and only slowly increasing interest and effort in utilizing the computer for the usual symbolic manipulations of mathematics is to be encouraged. New analytical techniques, when they can be found, offer the possibility for major breakthroughs. Examples include the d-bar method in inverse scattering theory, and soliton theory and other forms of integrability. The ability to engineer nonlinear systems without surprises requires an understanding of perturbations of the desired system. For example, how small must a perturbation be to retain integrability. Many times algebraic manipulations required to analyze even simple systems tax the patience and exceed the accuracy of the investigator. The availability of computer algebra systems, perhaps in the near future even on large personal computers, will hopefully lead to advances in insight similar to that produced by numerical experiment.

3. Signal Processing (RO 8.4.1.): A major objective is the development of faster algorithms for signal processing without sacrificing accuracy or numerical stability. Also, further work is needed to obtain effective digital filters for video signals that can perform in real time and which can be implemented with VLSI hardware. The goal here is to achieve fast filters with modest precision and acceptable accuracy. Develop and explore applications of fast and numerically robust algorithms for adaptive filtering in high speed data communications, in adaptive beam-forming and adaptive control, and in digital filtering. Links with scattering theory, harmonic analysis, and the mathematical operator theory will be explored. Another topic requiring research is systolic filters for VLSI implementation of digital filters. Develop robust techniques for detection of stochastic signals and estimation of signal parameters in the presence of noise and unpredicted interference. Extend modeling of signal input to non-Gaussian cases and develop processing techniques and robust data-smoothing procedures, including nonlinear filtering techniques. Develop techniques for housing dependent data. Develop robust linear filtering and smoothing designs for families of stationary signals, using minimax criteria. Develop robust n-step predictors for stationary processes. Improve robust data compression algorithms and design optimal quantizers for certain classes. Establish prediction and filtering theory for stable and other non-Gaussian processes. Develop theory and numerical techniques for estimating distributions from their Fourier transforms.

Develop robust detection procedures under non-Gaussian and mixing conditions.Develop finitely-additive stochastic integration for applications to nonlinear filtering. Investigate properties of median and other nonlinear filter. Study extremal theory of stationary processes under dependence conditions and inference for point processes.

4. Computer-Intensive Statistical Procedures (RO 8.4.4): Develop new methods to reduce the computational complexity in evaluating the reliability of complex systems. Develop efficient algorithms to implement complexity-reducing schemes as they develop and evolve. Develop more complete computer-based modeling to include considerations of maintainability and availability in reliability problems. Develop models that account for maintenance and repairs and allow for imperfect repair. Develop models for assessing reliability with censored data. Assess reliability for systems subject to aging, shock, or repair. Develop reliability models that allow component dependence. Develop an algebraic approach to network reliability problems. Develop improved methods for handling and displaying very large data sets and high-dimensional data. Develop interactive analysis capabilities for semi-automatic exploratory data analysis. Adapt recently developed statistical procedures that require large-scale computing capabilities to allow such statistical computing in small-scale, real-time environments. These procedures include resampling schemes (bootstrap, jackknife), cross-validation techniques, and robust procedrues for censored data.

5. Decentralized Systems (RO 8.4.2.): The goal is to develop mathematical techniques capable of handling complicated decisions problems for large scale systems where many conflicting requirements have to be met, especially when a large number of computations are required. Research is needed in mathematical models containing stochastic differential or difference equations for the description of the time evolution of decentralized systems, noisy state observations with delays, and memory of previous decisions for the information, plus cost functionals. Although most real problems are nonlinear, the game structure problems are so difficult that most of the progress will come first with linear models.

6. Approximate Models for Control of Distributed Parameter Systems (RO 8.4.7.): Develop numerical approximation schemes for control systems governed by partial and functional differential equations. Problems of convergence, rates of convergence and real time implementation will be studied to obtain an understanding of the errors introduced by approximate modeling. Research will be performed using the theory of operators and dynamical systems in Hilbert spaces. Topics include state space modelling of aeroelastic systems, or large space structures and of optical devices, approximation of infinite dimensional systems and large scale computing. Finite difference and finite element and modal techniques will be used to develop approximate models of distributed parameter models. Function errors, finite dimensional approximation theory and functional analysis will be used to study the effects of model reduction for infinite dimensional systems. Frequency domain methods will be analyzed and applied to various models of distributed parameter control systems.

APPLICATION TO AIR FORCE TECHNOLOGY PROGRAMS:

a. Provide collaborative computer support for decision making.

b. Improve software production and maintenance through intelligent software assistant.

c. Increase the accuracy and timeliness of information integration and analysis through knowledge-based processing techniques.

d. Provide system timing components which will have lower noise spectral characteristics and higher long term frequency stability.

e. Provide data to assess the feasibility/desirability of exploiting non-conventional HG propagation modes for surveillance and survivable communication purposes.

f. Provide adaptive interference analysis capability to reject unwanted interference.

g. Provide baseline capability to accurately recognize speech to enhance command and control capabilities and communications even in the presence of extreme communication link interference.

h. Improve measurement and detection capabilities of receivers and processors.

i. Realize mobile communication networks which are secure and bandwidth efficient.

j. Reduce the complex digital architecture required for image compression, and extend the image transmission capability to higher data rates and larger images.

k. Realize phase locked loops with extyended pull-in range and decreased acquisition time for improved secure communications.

l. Achieve methods for modeling of communication channels leading to increased channel capacity and better communication channel utilization.

m. Improve target detection and identification, and reduce the time and effort of photo-interpreters in finding targets.

n. Reduce software costs due to validation and testing of software, and improve reliability of software; reduce life cycle costs.

o. Improve VLSI design and systematized modular design procedures of general applicability.

p. Customize integrated circuits for low cost systems.

q. Improve the large scale hierarchical decision making in command situations.

r. Improve the reliability of computing and communication networks.

s. Achieve understanding of turbulent flows.

SUBAREA 8.4 FY 86 PLANNED FUNDING:

TASK NR	TITLE	TOTAL TASK FUNDS ($K)	TASK FUNDS SPTG SUBAREA 8.4 ($K)
2304A1	Mathematics of Dynamics and Control	2250	525
2304A3	Computational Mathematics	3000	200
2304A4	Mathematics of Physical, Chemical & Biological Systems	900	900
2304A5	Statistics and Probability	3100	1250
2304A6	Mathematics of Signal Processing and Communications	900	235
2304A8	Mathematical Optimization	900	300
2304A9	Applied Analysis	883	600
2304B1	Finite Mathematics	750	450
	TOTAL		4460

AFOSR Focal Point: Col D. Fujii
Telephone: (202) 767-4929

SPECIAL PROGRAMS

The Air Force supports research in all areas of science and technology which may yield solutions to problems of interest to the Air Force and which includes assurance of a strong scientific base to provide fundamental knowledge and new ideas essential to the future of the Air Force. Some of the research performed in support of that policy does not fit conveniently into a finite set of research objectives as stated in the AFSC Research Planning Guide. This narrative contains a description of FY 1986 plans for special programs. The applications of these programs are generally generic and intersect the full spectrum of Air Force requirements. Programs such as AFIT and USAFA support have the added advantage of productively using in-house Air Force academic resources in support of AFSC programs. Other programs should have a side benefit of increasing the pool of scientists and engineers who are familiar with Air Force requirements and available to DRS and other laboratory programs.

PROGRAM DESCRIPTION:

1. DOD-University Research Instrumentation Program: AFOSR, with the Army Research Office and the Office of Naval Research, will continue to participate in this five year program begun in fiscal year 1983 to upgrade university research instrumentation.

2. EOARD Programs in Research: AFOSR will provide funds through EOARD to support European and Middle Eastern research opportunities of special interest to the Air Force and to enhance communication with those scientific communities. Small procurements will permit Air Force Systems Command to take advantage of unique capabilities of a European or Middle Eastern investigator or facility. The procurements are coordinated in advance with representatives of Air Force laboratories interested in the programs. Cooperative international visits of researchers will be funded under the Window on Science Program.

3. AFOSR Far East Office Support: AFOSR staffs and funds a liaison office located in Tokyo, Japan. The office's professional scientific staff establishes and maintains technical contacts with researchers at educational, industrial, and government research organizations in Japan and other free world countries in the Far East to facilitate the interchange of scientific data.

4. FJSRL Commander's Fund: Opportunities for laboratory research of high potential payoff frequently arise outside the normal planning cycle. The Commander of FJSRL will select for pursuit those which he determines to be of sufficient importance to the Air Force. The FJSRL will provide support for USAF Academy faculty and cadet research conducted in the FJSRL on topics of mutual interest to the FJSRL and the researchers.

5. Summer Faculty Research/Graduate Student Summer Support and Minigrant Program: The purpose of these programs is to develop the basis for continuing research of interest to the Air Force at the institution of the faculty member; to stimulate continuing relations among faculty members and professional peers in the Air Force; to enhance the research interests and capabilities of scientific and engineering educators; and to provide follow-on funding for research of particular promise that was started under the Summer Faculty Research Program. Approximately 150 university faculty and 100 graduate students will be selected to perform research in Air Force laboratories for ten weeks. Each participant will provide a report of research to the program contractor who will consolidate the reports into a single publication. Approximately 75 minigrants will be awarded during FY 1986 to participants of the Summer Faculty Research Program.

6. University Resident Research Program (URRP): Approximately 25 faculty members will be brought into Air Force laboratories under the Intergovernmental Personnel Act. They will generally perform research in the laboratory for one year before returning to their university with a broadened awareness of Air Force research needs and operations.

7. Postdoctoral Associateship Program: This program provides funds to support research of outstanding postdoctoral scientists and engineers in Air Force laboratories. The program will continue to be administered for AFOSR by the National Academy of Sciences. Proposals from candidate postdoctoral scientists will be evaluated by a panel of five or more qualified scientists in order to select those with highest scientific merit and Air Force interest.

8. Air Force Studies Board: Supports studies, surveys, and analysis of specified problems arising in accomplishing research and technical objectives of AFSC. The National Academy of Sciences will convene a working panel during the summer. The study topic will be selected at a later date.

9. Air Force Institute of Technology (AFIT) Research: AFOSR will provide funds to be used by AFIT Faculty primarily to procure equipment needed by AFIT to conduct approved research programs.

10. AFOSR Commander's Fund: This fund provides the AFOSR Commander the flexibility to apply additional resources to areas of particular interest to the Air Force or to capitalize on targets of opportunity that arise during the year. Opportunities that arise outside the normal planning cycle tend to be high risk and to have high potential payoff. The Commander of AFOSR will select for funding those which he determines to be of sufficient importance to the Air Force.

11. In-house Support: AFOSR funds identified to provide for the operation of AFOSR.

ADDITIONAL AFOSR PUBLICATIONS

Research Interests, July 1985.

This book describes selected research interests of the Air Force Office of Scientific Research (AFOSR).

Recent Research Accomplishments of the Air Force Office of Scientific Research, May 1985.

This report is published to inform the scientific and technical community of some of the promising results of recent AFOSR research.

AFOSR Technical Report Summaries.

This report is published quarterly and consists of a brief summary of each AFOSR technical report received by AFOSR/XOT and submitted to the Defense Technical Information Center (DTIC).

These publications are available from:
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